FINAL PROJECT

PERFOMANCE OF ASPHALT CONCRETE - BINDER COARSE MIXTURE WITH GLASS POWDER FILLER AGAINST BATANGHARI RIVER WATER SUBMERSION

Submitted to The Universitas Islam Indonesia Yogyakarta as A Fulfillment of he Requirements to Obtain Civil Engineering Bachelor Degree

Gading Ananda Syahri
20511012

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Arranged by

Gading Ananda Syahri
20511012

Has been accepted as one of the requirements for
obtaining a Bachelor's degree in Civil Engineering

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By the Board of Examiners:

Supervisor	Examiner I	Examiner II
Ir. Muhamad Abdul Hadi, S.T., M.T.	**Prayogo Afang Pravitno, S.T., M.Sc.**	**Anggit Mas Arifudin, S.T., M.T.**
NIK: 215111307	**NIK: 205111303**	**NIK: 185111304**

Approved by,

Head of the Civil Engineering Undergraduate Program

25/9 2025

Ir. Yunalia Muntafi, S.T., M.T., Ph.D. (Eng)., IPM.

NIK: 095110101

PLAGIARISM DECLARATION

I hereby affirm that this Final Project report, submitted as a requirement for the completion of the Bachelor's Program in Civil Engineering, Faculty of Civil Engineering and Planning, Universitas Islam Indonesia, is solely the result of my own efforts. Any portions that draw upon or cite the work of others have been duly acknowledged in accordance with academic writing norms, standards, and ethical guidelines. Should it later be found that any part of this report is not original or contains elements of plagiarism, I fully accept the possibility of sanctions, including the annulment of the degree conferred, in line with applicable laws and regulations.

Yogyakarta, 22 August 2025

Declaring the statement,

Gading Ananda Syahri

(20511012)

DEDICATION

"In family life, love is the oil that eases friction, the cement that binds closer together, and the music that brings harmony."- Friedrich Nietzsche

With heartfelt gratitude and a humble soul, This modest work I dedicate to my beloved parents, whole. For ceaseless prayers that light my way, For boundless love, pure as the day, And sacrifices, endless, selfless, and grand, You've held my heart, my dreams, my hand. Your fervor, love, and tender grace Fueled my strength to run this race. May this creation, though small it seems, Reflect my devotion and fulfill your dreams, A quiet ode to honor and pride, For my cherished Father and Mother, forever by my side.

This work I also dedicate to my beloved sister, A constant beacon through joy and bitter. Your steadfast support, your prayers sincere, Your boundless love, forever near, Have been my strength, my heart's sweet guide, Through every step, you've stood by my side. May this small triumph, humbly won, Spark pride and inspiration, shared as one.

Syahri's, ∞

PREFACE

All praise and gratitude are due to Allah SWT for His guidance and blessings, which have allowed the author to complete this Final Project entitled *"Performance of Asphalt Concrete-Binder Course Mixture with Glass Powder Filler Against Batanghari River Water Submersion."* This project is presented as part of the requirements to fulfill the undergraduate degree in Civil Engineering, Faculty of Civil Engineering and Planning, Universitas Islam Indonesia, Yogyakarta.

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The author earnestly hopes that this Final Project can offer meaningful insights and support ongoing discussions and advancements in the field of Pavement Engineering. Although it has certain limitations, it is expected that this work may serve as a stepping stone for future research.

Yogyakarta, 25 August 2025

Author,

Gading Ananda Syahri

(20511012)

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LIST OF ABBREVIATIONS

AASHTO	=	American Association of State Highway and Transportation Officials
AC	=	Asphalt Concrete
AC-BC	=	Asphalt Concrete – Binder Course
AC-WC	=	Asphalt Concrete – Wearing Course
ASTM	=	American Society for Testing and Materials
CL	=	Cantabro Loss
GP	=	Glass Powder
IRS	=	Index of Retained Strength
ITS	=	Indirect Tensile Strength
MQ	=	Marshall Quotient
MS	=	Marshall Standard
OAC	=	Optimum Asphalt Content
SMA	=	Stone Mastic Asphalt
SNI	=	*Standar Nasional Indonesia*
SSD	=	Saturated Surface Dry
TSR	=	Tensile Strength Ratio
VFWA	=	Void Filled with Asphalt
VITM	=	Void in Total Mixture
VMA	=	Void in Mineral Aggregate

LIST OF NOTATIONS

a	=	Percentage of asphalt by aggregate (%)
A	=	Weight of pycnometer with lid (gr)
A	=	Percentage of coarse aggregate (%)
b	=	Percentage of asphalt by mix (%)
B	=	Weight of pycnometer filled with water (gr)
B	=	Percentage of fine aggregate (%)
c	=	Weight of specimen before immersion (gr)
C	=	Weight of pycnometer filled with asphalt (gr)
d	=	Weight of the specimen in SSD condition (gr)
D	=	Diameter sample (cm)
D	=	Weight of pycnometer filled with water and asphalt (gr)
e	=	Weight in water (gr)
f	=	Volume (cm^3)
F1	=	Specific gravity of coarse aggregate
F2	=	Specific gravity of fine aggregate
g	=	Density value (gr/cm^3)
h	=	Theoretical maximum specific gravity mixture
K	=	constant
l	=	VMA value (%)
L	=	Percentage of weight loss (%)
m	=	VFWA value (%)
Mi	=	Weight after abrasion (gr)
Mo	=	Weight before abrasion (gr)
n	=	VITM value (%)
P	=	Peak load (kg)
Pb	=	Asphalt content (%)
q	=	Stability value (kg)

r	=	Flow value (mm)
S1	=	Average MS value after immersion for 30 minutes (kg)
S2	=	Average MS value after immersion for 24 hours (kg)
s	=	Specimen thickness correction factor
t	=	Thickness of sample (cm)
T_1	=	Average of ITS value without immersion (kg)
T_2	=	Average of ITS after 24 hours of immersion (kg)

ABSTRACT

Each year, during Indonesia's rainy season, flooding becomes a recurring problem, especially along the Batanghari River in Jambi City. Intense rainfall frequently leads to waterlogging in multiple areas, with river levels rising sharply and overflowing during heavy downpours. Inadequate handling of these conditions can result in road damage, including decreased pavement stability and durability due to extended water exposure.

This research evaluates the efficacy of glass powder as a substitute filler in AC-BC mixtures to improve durability, structural strength, and volumetric characteristic under flood-related soaking conditions. The experimental approach involved creating AC-BC mixtures with varying glass powder filler substitutions (0%, 25%, 50%, 75%, and 100%) and immersing them in Batanghari River water for three durations (0, 24, and 48 hours). Performance was assessed using Marshall standard tests, ITS, IRS, TSR, and CL tests.

The results of this study indicate that a 75% substitution of glass powder with 24-hour immersion provides optimal performance. Using 0% glass powder filler substitution as a reference, the mixture shows improvements in stability by 2%, MQ by 6.45%, VFWA by 1.45%, with density remaining unchanged, while flow decreases by 4.29%, VITM by 6.98%, and VMA by 1.38%. The ITS test demonstrates an increase in tensile strength of 1.82%, and the Cantabro test shows a minimal mass loss of 0.32%. However, reductions in TSR by 5.25% and IRS by 1.59% indicate a degree of vulnerability to prolonged water exposure. This study underscores the potential of glass waste as an environmentally friendly filler material for asphalt pavements in flood-prone areas.
.

Keywords: Glass Powder, Filler, AC-BC, Mixture Performance

ABSTRAK

Setiap tahun, pada musim hujan di Indonesia, banjir menjadi masalah yang berulang, khususnya di sepanjang Sungai Batanghari di Kota Jambi. Curah hujan yang tinggi sering menyebabkan genangan air di berbagai wilayah, dengan debit sungai meningkat tajam dan meluap saat hujan lebat. Penanganan yang kurang memadai dapat mengakibatkan kerusakan jalan, termasuk penurunan stabilitas dan daya tahan perkerasan akibat paparan air yang berkepanjangan.

Penelitian ini mengevaluasi efektivitas serbuk kaca sebagai bahan pengganti filler dalam campuran AC-BC untuk meningkatkan daya tahan, kekuatan struktur dan karakteristik volumetrik terhadap kondisi genangan banjir. Metode eksperimen dilakukan dengan membuat campuran AC-BC dengan variasi substitusi serbuk kaca (0%, 25%, 50%, 75%, dan 100%) serta perendaman dalam air Sungai Batanghari selama tiga durasi (0, 24, dan 48 jam). Kinerja campuran diuji menggunakan metode standar Marshall, ITS, IRS, TSR, dan CL.

Hasil penelitian menunjukkan bahwa substitusi serbuk kaca sebesar 75% dengan perendaman 24 jam memberikan kinerja optimal, dengan 0% substitusi Filler GP sebagai acuan, meningkatkan stabilitas 2%, MQ 6,45%, VFWA 1,45%, density stagnan, serta menurunkan nilai flow sebesar 4,29%, VITM 6,98%, VMA 1,38% . Uji ITS menunjukkan peningkatan kuat tarik sebesar 1,82%, dan hasil uji Cantabro memperlihatkan kehilangan massa yang minimal sebesar 0,32%. Namun, penurunan nilai TSR sebesar 5,25% dan IRS sebesar 1,59% mengindikasikan adanya kerentanan terhadap paparan air dalam jangka waktu lama. Studi ini menegaskan potensi limbah kaca sebagai material filler ramah lingkungan untuk perkerasan aspal di daerah rawan banjir.

Kata kunci: *Serbuk Kaca*, Filler, AC-BC, *Performa Campuran*

CHAPTER I
INTRODUCTION

1.1 Background

Every year, flood issues arise during the rainy season in Indonesia, particularly along the Batanghari River in Jambi City. High rainfall often causes periodic waterlogging in several areas. Additionally, river water levels can overflow significantly during heavy rainfalls. Pryastuti, et al. (2021) conducted a study on mapping flood vulnerability levels in Jambi City using scoring and overlay methods based on geographic information systems (GIS). The research indicates that most areas of Jambi City are vulnerable to flooding, except for the South Jambi District, which is relatively safe. Poor management of these situations can lead to road damage, such as reduced stability and resilience of pavements due to prolonged waterlogging.

According to Khamid and Izazi (2019), their research states that water is one of the primary factors causing road damage. High acidity levels in rainwater can accelerate oxidation, weakening the bond between asphalt and aggregate, thus hastening surface road deterioration. This condition can worsen if water pooling persists for more than 24 hours (the standard for Marshall residual strength), and the road is subjected to vehicle loads exceeding set limits. Water pooling can damage road surfaces because it weakens the bond between small rocks and asphalt binding materials.

Nurhudayah (2009) studied that water pooling penetrating into road pavements can cause cracking in the road pavement. This is due to the weakened bearing capacity of the subgrade resulting from fluctuations in groundwater levels at the location. According to Muliawan (2019), if water pooling is not properly drained due to drainage system issues, water can infiltrate into the asphalt layer and damage the layers above it. Irwansyah and Rosyad (2019) states that water causes aggregates to detach from the surface layer (raveling) or can be termed as

anti-adhesion. Road pavement is a combination of aggregate and binder materials used to handle traffic loads. According to AASHTO (1993), a road pavement is a combination of surface, base, and subgrade layers positioned above the subgrade to support traffic loads and distribute them to the subgrade. The main components of a road pavement mixture include aggregate, asphalt, and filler materials. Asphalt is crucial in road pavement construction. The asphalt concrete binder course (AC-BC) serves as the binding material between the upper base course and the wearing course layers of the road surface structure. AC-BC consists of dense and continuous aggregates and is typically used for roads with heavy traffic. According to Masykur (2016), AC-BC mixture is a wearing surface layer that protects the pavement from water, provides a smooth surface, and exhibits dense and even characteristics. This aims to ensure safety and comfort for road users while distributing loads to the layers beneath it.

Typically, the filler material for AC-BC mixture is commonly produced from stone crushing machines, which are becoming increasingly limited and expensive. One alternative is to use materials derived from household waste, such as glass powder waste. According to Andililo, et al. (2019) Glass has good resistance to weather and chemical attacks. Glass powder waste also has high adhesion properties because it contains silicon dioxide (reactive silica). In research conducted by Simone, et al. (2017), glass waste powder contains around 30% silica (SiO2), and contains calcium oxide (CaO), alumina (Al2O3), and sodium oxide (Na2O) with percentages ranging from 10%. up to 19%. Other oxide content is less than 1%. Lin, et al. (2008) stated that glass waste powder has the ability to participate in pozzolanic reactions which increase the positive characteristics of a mixture. It can be concluded that glass powder waste can be used as a filler in coarse asphalt concrete mixtures.

Nasrul, et al. (2022) conducted research on glass powder as a filler in AC-BC asphalt mixtures, the research results showed that, at an optimum asphalt content of 5.8%, adding 1–5% glass filler reduced Marshall Stability (MS) and Voids Filled with Asphalt (VFA). While flow values at 1–4% substitution met

specifications, the 5% level exceeded the acceptable limits for VIM and flow, making it unsuitable for AC-BC surface layers.

Mawarni and Fauziah (2019) conducted a study on the effect of seawater immersion on the characteristics of porous asphalt with and without the addition of rubber tire waste. Their findings revealed that in porous asphalt mixtures using Pen 60/70 asphalt binder and rubber asphalt, prolonged exposure to seawater led to reduced stability, flow, and Marshall Quotient (MQ) values. The longer the immersion period, the more the asphalt's load-bearing capacity diminished.

The author tried to conduct research on performance of AC-BC mixture with glass powder filler against Batanghari river water submersion. The author chose the AC-BC type of pavement because AC-BC is a pavement that is commonly used in urban areas in Jambi, and the author also used filler with glass powder waste material considering the relatively cheap cost, reducing waste, and stronger to withstand water penetrated the pavement. The author's hope is that this research will be an option for the government to make road pavements that are stronger against submersion of the Batanghari River water, Jambi.

1.2 Problem Formulation

Based on the background that has been prepared, the problems that will be discussed in this research are as follows:

1. What is the effect of glass powder as filler substitute AC-BC layer on structural strength characteristics based on the various submersion times of Batanghari River water ?
2. What is the effect of glass powder as filler substitute AC-BC layer on Volumetric characteristics based on the various submersion times of Batanghari River water ?
3. What is the effect of glass powder as filler substitute AC-BC layer on durability characteristics based on the various submersion times of Batanghari River water ?

1.3 Purpose of Study

Based on the problem formulation mentioned above, the research objectives to be achieved are as follows.

1. Determine the effect of glass powder as filler substitute AC-BC layer on structural strength based on the various submersion times of Batanghari River water.
2. Determine the effect of glass powder as filler substitute AC-BC layer on Volumetric characteristics based on the various submersion times of Batanghari River water.
3. Determine the effect of glass powder as filler substitute AC-BC layer on durability characteristics based on the various submersion times of Batanghari River water.

1.4 Significance of Study

Below here is the significance of the study, namely:

1. The study provides knowledge regarding filler substitution using glass powder, particularly in the AC-BC asphalt layer mixture relying upon various submersion times from Batanghari River water.
2. The study enables an understanding of the advantages of using glass powder as filler substitution in AC-BC asphalt layer mixture relying upon various submersion times from Batanghari River water.

1.5 Scope and Limitation of The Research

The limitations in this research aim to help the author stay focused and ensure that the research topic does not deviate, so that the results obtained are optimal. The following are the limitations applied in this research.

1. The regulations used are AASHTO and General Specifications for Highways 2018 Revision 2.
2. The binding material used is Pertamina Pen 60/70 asphalt.
3. Coarse aggregate obtained from the Highway Laboratory of the Department of Civil Engineering, Faculty of Civil Engineering and Planning, Islamic University of Indonesia.

4. Fine aggregate obtained from the Highway Laboratory of the Civil Engineering Department, Faculty of Civil Engineering and Planning, Islamic University of Indonesia.
5. Glass powder filler substitute obtained from Pasuruan City, East Java Province.
6. The glass powder filler substitution variations used are 0%, 25%, 50%, 75%, and 100% against stone dust filler
7. The soaking used is river water obtained by taking water samples in the Batanghari River, Batanghari.
8. The influencing variable studied is soaking time, namely 0 hours, 24 hours and 48 hours. This variable is obtained based on real events in the field
9. The filler material used is stone dust.
10. Testing was carried out at the Highway Laboratory of the Civil Engineering Department, Faculty of Civil Engineering and Planning, Islamic University of Indonesia.
11. This research did not test the mineral content contained in glass powder.

CHAPTER II
LITERATURE REVIEW

2.1 Review of Previous Research

The research method to be used is related to several previous studies. Some of these studies discuss the characteristics of asphalt mixtures with various alternative replacement fillers, the use of glass powder waste as a filler substitute, and the effect of water immersion on road pavement.

2.1.1 Characteristics of Asphalt Mixtures with Various Alternative Fillers Replacement

Filler or filling material is a substance that typically passes through a No. 200 sieve and serves to fill the spaces between coarse aggregate particles in a framework to reduce the volume of voids, increase density, and stabilize the mass. Filler helps reduce the size of air voids and increases the overall density of the mass.

In the study conducted by Bancin, et al. (2021) on the effect of using red soil as a filler in AC-BC mixtures to determine its impact on the characteristics of Marshall parameter properties, it was found that the use of red soil as a filler replacement resulted in an increased use of filler content, which significantly affected the asphalt mixture. The stability value obtained met the specified requirements, namely the Bina Marga 2018 Specifications Division 6 Revision II. The use of red soil dust that passes through a No. 200 sieve as a filler replacement for stone dust in AC-BC asphalt concrete mixtures using 60/70 penetration asphalt can meet the requirements of the Bina Marga 2018 General Specifications.

Gunawan and Sari(2021) conducted a study on the use of limestone as a filler in AC-BC mixtures to determine its effect on the mixture using the Marshall testing method. The testing results met the requirements, making it a suitable reference for the development of the Job Mix Formula for field application.

Yuniarti, et al. (2019) conducted a study on the use of glass waste as a filler in hot

asphalt pavement mixtures. The results showed that using glass waste at a proportion of 75% of the total filler weight increased the stability and stiffness of the mixture, making it more capable of bearing loads. The mixture with 75% glass waste filler produced lower VIM and VMA values and higher VFB values, indicating that the mixture has strong bonding and interlocking properties, resulting in smaller voids and a thicker asphalt film. Based on the results of the Marshall immersion and Cantabro loss tests, the mixture with this proportion is more resistant to water immersion, leading to higher durability and better resistance to potential disintegration.

Widyastuti and Widayanti (2023) conducted a study on the utilization of coconut shell ash as a filler substitute in AC-BC mixtures. It was concluded that the stability, VMA, and MQ values met all the required Marshall parameters, while the flow, VIM, and VFA values did not yet meet the Bina Marga 2018 specifications. Based on the Marshall parameters, the most optimal value was at KAO 6,1% with a 3,5% filler variation.

2.1.2 Use of Glass Powder Waste as Filler Substitute

Ogundipe and Nnochiri (2018) conducted research on the evaluation of the effects of waste glass in asphalt concrete using the marshall test. The results show the stability of asphalt concrete with waste glass increases as the glass content increases up till 18% and decreases with addition of 20% glass waste.

Nasrul, et al. (2022) conducted a study on the effect of using glass powder waste as an additional filler material in the surface layer of AC-BC on Marshall characteristics. In testing hot mix asphalt for AC-BC, after determining the optimum asphalt content of 5,8%, the addition of various percentages of glass filler from 1% to 5% of the total filler weight resulted in a decrease in Marshall Stability (MS) and Voids Filled with Asphalt (VFA). However, the flow values with 1% to 4% glass filler still met the specified requirements, but at 5%, the flow did not meet the standards because the VIM and flow values exceeded the desired limits for the AC-BC surface layer.

Syafi', et al. (2024) studied the Characteristics of Using Glass Powder Waste in Asphalt Laston Mixture (AC-BC) Against Marshall Parameters. The result was the effect of using waste glass powder as a substitute filler in AC-BC mixtures was investigated through the Marshall method, assessing parameters such as Voids in Mineral Aggregate (VMA), Voids Filled with Bitumen (VFB), Voids in Mix (VIM), Stability, Flow, and Marshall Quotient. Optimal performance was observed with a 2,5% filler content and 6,0% asphalt content, resulting in a VMA of 14,15%, VFB of 77,6%, VIM of 3,20%, Stability of 2051,38 kg, Flow of 2,14%, and Marshall Quotient of 1065,54 kg. All measured parameters satisfied the requirements outlined in the General Specifications of Bina Marga (Revision 2) 2018.

Choudhary, et al. (2021) conduct a research about Utilization of Waste Glass Powder and Glass Composite Fillers in Asphalt Pavement. Choudhary stated that Using glass powder (GP) as waste and composite filler offers an effective, eco-friendly solution for glass waste disposal. Incorporating GP and glass (GL) fillers in asphalt mixes has been shown to enhance engineering performance while being more cost-effective and environmentally sustainable.

2.1.3 Effect of Water Immersion on Road Pavement

Water immersion can damage road pavement. This is because water, especially rainwater with high acidity, can accelerate oxidation, weaken the bond between asphalt and aggregate, and thus hasten the deterioration of the road surface.

Gumilang (2017) studied the impact of freshwater immersion on the durability and Marshall properties of Asphalt Concrete Binder Course (AC-BC) mixtures. It was concluded that the longer the AC-BC mixture is immersed in freshwater, the lower its durability. This is evident from the decrease in the values of the Residual Strength Index (IKS), First Durability Index (IDP), and Second Durability Index (IDK).

In the study by Arifin and Tugiman (2022) on the analysis of the effect of immersion time on the stability and flow of AC-BC pavement, the researchers

stated that the duration of immersion has a significant impact on the stability and flow of the pavement mixture. The longer the pavement is immersed at a specific temperature, the lower its stability value becomes, while the flow value increases. This results in a reduced bond between the asphalt and the aggregate.

Mawarni dan Fauziah (2019) conducted a study on the effect of seawater immersion on the characteristics of porous asphalt with and without the addition of rubber tire waste. The results showed that in porous asphalt mixtures with Pen 60/70 asphalt binder and rubber asphalt, there was a decrease in stability, flow, and MQ values as the duration of immersion in seawater increased. The longer the porous asphalt mixture was immersed in seawater, the lower its ability to bear loads became.

Harahap, et al. (2022) studied the effect of peat water immersion on the durability of AC-WC. It was concluded that a 7-day peat water immersion resulted in the highest Cantabro Loss value of 23,6%, meeting the requirement of being below 25%. The lowest stability value after peat water immersion was 1805 kg. Each increase in the duration of peat water immersion caused a decrease in stability values. The First Durability Index (IDP) for peat water immersion was 37%, and the Second Durability Index (IDK) was 34%.

In a study conducted by Badry, et al. (2021) on the influence of peat water on the Marshall characteristics of AC-BC mixtures using palm oil clinker ash as a filler, it was concluded that the use of peat water as soaking water led to a decrease in the Marshall characteristics value. This resulted in a decrease in the Residual Strength Index (IRS) with an increase in the soaking duration.

2.2 Comparison of Previous Research with the Research to be Conducted

The above studies can be summarized in a table as follows.

Table 2.1 Comparison with Previous Research

No	Aspect	Previous Research						Current Research
		Mawarni and Fauziah (2019)	**Yuniarti, et al (2019)**	**Badry, et al (2021)**	**Vianda, et al (2021)**	**Nasrul, et al (2022)**	**Harahap, et al (2022)**	**Syahri (2024)**
1	**Research Title**	The effect of sea water soak on asphalt porous characteristics with and without waste of rubber tire waste as an asphalt addictive	The Use of Glass Waste as a Filler in Hot Asphalt Pavement Mixtures	The Effect of Peat Water on Marshall Characteristics in Asphalt Concrete-Binder Course (AC-BC) Mixtures Using Palm Kernel Ash as a Filler	Marshall Characteristics of Asphalt Concrete-Binder Course (AC-BC) Mixtures with Limestone Ash Filler	The Effect of Using Glass Powder Waste as an Additional Filler in the Surface Layer of AC-BC on Marshall Characteristics	The Effect of Peat Water Immersion on the Durability of AC-WC	Performance of Asphalt Concrete – Binder Coarse Mixture With Glass Powder Filler Against Batanghari River Water Submersion

Source: Mawarni and Fauziah (2019), Yuniarti, et al. (2019), Badry, et al. (2021), Vianda, et al. (2021), Nasrul, et al. (2022), Harahap, et al. (2022)

Continuation of Table 2.1 Comparison with Previous Research

No	Aspect	Previous Research						Current Research
		Mawarni and Fauziah (2019)	**Yuniarti, et al (2019)**	**Badry, et al (2021)**	**Vianda, et al (2021)**	**Nasrul, et al (2022)**	**Harahap, et al (2022)**	**Syahri (2024)**
2	**Mixture Type**	Porous Asphalt	Ashpalt Concrete – Binder Coarse (AC-BC)	Ashpalt Concrete – Binder Coarse (AC-BC)	Ashpalt Concrete – Binder Coarse (AC-BC)	Ashpalt Concrete – Binder Coarse (AC-BC)	Ashpalt Concrete – Wearing Coarse (AC-WC)	Ashpalt Concrete – Binder Coarse (AC-BC)
3	**Binding Material Types**	Pen 60/70	Pen 60/70	Pen 60/70	Pen 60/70	Pen 60/70	Pen 60/70	Pen 60/70
4	**Filler Type**	Rubber Tire Waste	Glass Waste	Palm Kernel Ash	Limestone Ash	Glass Powder Waste	-	Glass Powder
5	**Water Immersion Type**	Sea Water	-	Peat Water	-	-	Peat Water	Batanghari River Water
6	**Research Type**	Stability, flow, MQ, ITS, Cantabro	VIM, VMA, and VFB	Marshall Characteristic and IKS	Marshall characteristic, Stability, flow, MQ	Stability, MQ, and VFA	Cantabro loss	Marshall characteristic, ITS, IRS, TSR, and CL

Source: Mawarni and Fauziah (2019), Yuniarti, et al. (2019), Badry, et al. (2021), Vianda, et al. (2021), Nasrul, et al. (2022), Harahap, et al. (2022)

Continuation of Table 2.1 Comparison with Previous Research

No	Aspect	Previous Research						Current Research
		Mawarni and Fauziah (2019)	**Yuniarti, et al (2019)**	**Badry, et al (2021)**	**Vianda, et al (2021)**	**Nasrul, et al (2022)**	**Harahap, et al (2022)**	**Syahri (2024)**
7	**Result**	The study found that all mixtures had "moderate drainage" permeability. As seawater immersion time increased, the porous asphalt mixtures with Pen 60/70 asphalt and rubber asphalt showed a decrease in stability, flow, MQ,	The result revealed that using 75% waste glass by weight of filler improved stability and stiffness. Mixtures with this proportion of waste glass filler showed smaller VIM and VMA values and a larger VFB, indicating strong bonding	The KAO value recorded the highest stability at 906.53 kg with a 4% filler variation after 0.5 hours of immersion, while the lowest stability was observed at 505.33 kg with a 0% filler variation after 24 hours of immersion.	The study results show that Marshall characteristics such as VMA and VFA values tend to increase, whereas VIM, Flow, Stability, and Marshall Quotient values tend to decrease with different filler variations. The KAO	The study results indicate that incorporating waste glass at levels of 1%, 2%, 3%, 4%, and 5% leads to lower stability values, Marshall quotient, and VFA compared to the mixture	The highest value after 7 days of immersion in peat water was 23.6%, which meets the Cantabro Loss requirement of being less than 25%. The lowest stability value recorded after immersion in peat water was 1805 kg.	This study found that a 75% glass powder substitution with 24-hour immersion yielded optimal performance. Compared to the 0% reference, the mixture showed higher stability (2%), MQ (6.45%), VFWA (1.45%), and ITS (1.82%), with density unchanged.

Source: Mawarni and Fauziah (2019), Yuniarti, et al. (2019), Badry, et al. (2021), Vianda, et al. (2021), Nasrul, et al. (2022), Harahap, et al. (2022)

Continuation of Table 2.1 Comparison with Previous Research

No	Aspect	Previous Research						Current Research
		Mawarni and Fauziah (2019)	**Yuniarti, et al (2019)**	**Badry, et al (2021)**	**Vianda, et al (2021)**	**Nasrul, et al (2022)**	**Harahap, et al (2022)**	**Syahri (2024)**
7	**Result**	and Indirect Tensile Strength (ITS) values. The Index of Retained Strength also declined with longer immersion durations. However, the Cantabro test results indicated that damage increased with extended seawater exposure.	and interlocking properties, which led to reduced voids and a thicker asphalt binder film. Additionally, Marshall immersion and Cantabro loss tests showed that mixtures with this waste glass proportion were more resistant to water immersion, resulting in higher durability.	Additionally, the IKS value that meets the Standard Specification of Bina Marga 2018 was only achieved at 3 hours of immersion time across all filler variations, where the maximum allowable reduction in stability is 90% of the original value.	values obtained were 5%, 5%, 5,1%, 5,5%, 5,6%, 5,8%, 5,9%, and 6,4%. According to the Bina Marga 2010 specifications, adding 1% and 2% filler resulted in a KAO value of 5,5%.	with 0% glass filler. Conversely, as the glass filler content increases to 1%, 2%, 3%, 4%, and 5%, there is a rise in flow values, VMA, and VIM, while the 0% variation shows lower values than those observed with the glass filler.	Stability values consistently decreased as the immersion duration increased. The first durability index (IDP) after immersion in peat water was 37%, while the second durability index (IDK) was 34%.	Flow, VITM, and VMA decreased, while Cantabro mass loss was minimal (0.32%). However, TSR (−5.25%) and IRS (−1.59%) indicated some vulnerability to prolonged water exposure.

Source: Mawarni and Fauziah (2019), Yuniarti, et al. (2019), Badry, et al. (2021), Vianda, et al. (2021), Nasrul, et al. (2022), Harahap, et al. (2022)

CHAPTER III
THEORITICAL BASIS

3.1 Road Pavement

Road pavement is a combination of aggregate materials and binders used to handle traffic loads. Swardana (2020) defines road pavement as a structure consisting of various layers that are integrated with each other from a mixture of specific materials. The main function of each layer is to reduce the load that occurs on top and then distribute it to the layers below. According to AASHTO (1993), road pavement is a combination of surface layers, base layers, and subgrade that are positioned above the subgrade to support traffic loads and transfer them to the subgrade.

According to Sukirman (1993), there are three types of pavement construction differentiated based on the type of binder material, namely:

1. Flexible Pavement

   This type of pavement uses asphalt as the binder material. It is flexible, especially when hot. The pavement layer functions to support and distribute traffic loads to the subgrade.

2. Rigid Pavement

   A pavement that uses cement (Portland Cement) as the binder material. It consists of concrete slabs and a base layer on top of the subgrade.

3. Composite Pavement

   It is a rigid pavement combined with flexible pavement, which can be flexible pavement over rigid pavement or vice versa.

Several types of layers that function to distribute traffic loads are as follows:

1. Surface Course It is a pavement layer located on the surface or at the topmost level. This layer has the following functions.

a. It serves as the wearing course due to the friction from vehicle wheels and is influenced by weather conditions.

b. According to Sukirman (1993), it is a layer that distributes the vehicle or traffic load to the layer below.

2. Base Course, It is the pavement layer located between the base layer and the surface layer. Its functions are as follows.

a. A pavement layer that functions to resist lateral forces from vehicle wheel loads and distribute them to the underlying layers.

b. Drainage layer for the base layer.

c. Support layer for the surface layer.

3. Sub Base Course, It is the pavement layer located below the upper base layer and directly in contact with the subgrade. Its functions are as follows.

a. As a drainage layer to prevent water from accumulating in the base.

b. To prevent fine particles from the subgrade from rising into the upper base layer.

c. To transfer traffic loads to the subgrade.

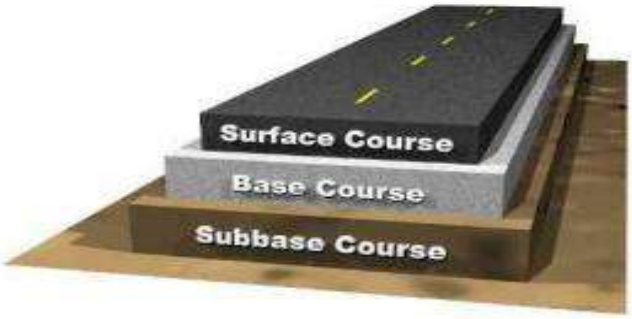


Figure 3.1 Flexible Pavement Layers

(Source : Fabian, 2023)

3.2 Flexible Pavement Component

The components required for the construction of flexible pavements include coarse aggregate, fine aggregate, filler, and additives, which are selected based on the type of mix to be used. The explanation of each component is as follows:

3.2.1. Aggregate

Aggregate is a collection of crushed stone, gravel, sand, or other minerals, either natural or artificial. Aggregates function to support traffic loads, making them a crucial component in road pavement construction. Aggregates are the primary component in hot mix asphalt, accounting for about 95% of the mix's weight. Therefore, road pavements rely heavily on aggregates and other materials in the mix. Aggregates can be divided into two types:

1. Coarse Aggregate

According to Bina Marga (2018), coarse aggregate in the mixture design has a function to withstand loads and must be retained on sieve No. 4 or 4.75 mm in wet and clean conditions. This aggregate must be hard, durable, free from clay or prohibited materials, and meet existing provisions. Coarse aggregate must come from machine-crushed stone and be prepared in nominal sizes according to the type of mixture specified. Coarse aggregate angularity refers to the percentage of aggregate weight greater than 4.75 mm or that meets the test based on *SNI* 7619:2012. Coarse aggregate testing specifications can be seen in Table 3.1.

Table 3.1 Specifications of Coarse Aggregate in AC-BC Mixtures

Test Type			**Testing Method**	**Value (%)**
Aggregate Shape Stability in Solution		Sodium sulfate	*SNI* 3407:2008	Max 12
		Magnesium sulfate		Max 18
Abrasion Resistance Using the Los Angeles Machine	Modified AC Mix and SMA	100 revs	*SNI* 2417:2008	Max 6
		500 revs		Max 30
	All other types of asphalt mix with graded aggregates	100 revs		Max 8
		500 revs		Max 40

Source: Bina Marga (2018)

Continuation of Table 3.1 Specifications of Coarse Aggregate in AC-BC Mixtures

Test Type		Testing Method	Value (%)
Aggregate Adhesion to Asphalt		*SNI* 2439:2011	Max 95
Crushed Particles in Coarse Aggregate	SMA	*SNI* 7619:2012	100/90*)
	Other		95/90**)
Flat and Elongated Particles	SMA	ASTM D4791-10 Ratio 1 : 5	Max 5
	Other		Max 10
Material Passing Through the No. 200 Sieve		*SNI* ASTM C117 : 2012	Max 1

Notes:
95/90 indicates that 95% of the coarse aggregate has one or more fractured faces, and 90% of the coarse aggregate has two or more fractured faces.

Source: Bina Marga (2018)

2. Fine Aggregate

Fine aggregate can come from various sources and must consist of crushed stone that passes through a No. 4 sieve. The main function of fine aggregate is to provide stability and reduce permanent deformation in the pavement through interlocking and friction between particles. The requirements for fine aggregate can be seen in Table 3.2.

Table 3.2 Specifications of Fine Aggregate in AC-BC Mixtures

Test Type	Testing Method	Value (%)
Sand Equivalent Value	*SNI* 03-4428-1997	Min 50
Void Content Test without Compaction	*SNI* 03-6877-2002	Min 45
Clay Clumps and Easily Fractured Particles in Aggregate	*SNI* 03-4141-1996	Max 1
Aggregate Passing Through the No. 200 Sieve	*SNI* ASTM C117:2012	Max 10

Source : Bina Marga (2018)

3.2.2. Filler

Filler is mineral dust that passes through a No. 200 sieve. Its requirements must comply with *SNI* 03-6723-2002, and when tested with sieving according to *SNI* ASTM C136-2012, it must contain at least 75% of material passing through the No. 200 sieve by weight. The functions of filler in asphalt concrete mixtures are as follows:

1. As a material to fill the voids between aggregate particles.
2. To enhance the bonding capacity of the asphalt concrete.
3. To improve the stability of the mixture.
4. To reduce the decrease or plastic flow.

3.2.3. Aggregate Gradation

Aggregate gradation is the distribution of aggregate particles according to their sizes and has a broad impact on the overall quality of the pavement. This gradation is obtained by sieving the material through a set of screens, starting with the largest openings at the top and progressing to the smallest openings at the bottom before the pan. Aggregate gradation is a crucial factor in determining the stability of the pavement. The gradation requirements for aggregates can be seen in Table 3.3.

Table 3.3 Aggregate Gradation of AC-BC Mixture

Sieve size		**% Weight pass**
ASTM	**(mm)**	**Laston (AC-BC)**
1”	25	100
¾”	19	90 – 100
½”	12,5	75 – 90
⅜”	9,5	66 – 82
No.4	4,75	46 – 64
No.8	2,36	30 – 49
No.16	1,18	18 – 38
No.30	0,600	12 – 28

Source : Bina Marga (2018)

Continuation Table 3.3 Aggregate Gradation of AC-BC Mixture

Sieve size		% Weight pass
ASTM	**(mm)**	**Laston (AC-BC)**
No.50	0,300	7 – 20
No.100	0,150	5 – 13
No.200	0,075	4 – 8

Source : Bina Marga (2018)

3.2.4. Asphalt

Asphalt is a material that is solid to somewhat solid at room temperature and has thermoplastic properties. Asphalt will melt when heated to a certain temperature and solidify again when the temperature drops. The asphalt used in this study is asphalt with a PEN 60/70 grade. The requirements for AC 60/70 hard asphalt can be seen in Table 3.4.

Table 3.4 Specification of Asphalt AC 60/70

No	Test type	Standard	Specification value
1	Specific Gravity	*SNI* 2441: 2011	≥ 1,0
2	Penetration at 25ºC (0,1 mm)	*SNI* 2456: 2011	60 – 70
3	Ductility at 25 ºC (cm)	*SNI* 2432: 2011	≥ 100
4	Flash Point (ºC)	*SNI* 2433: 2011	≥ 232
5	Solubility in TCE (%)	AASHTO T44-14	≥ 99
6	Softening Point (ºC)	*SNI* 2434: 2011	≥ 48

Source: Bina Marga (2018)

3.3 Glass Powder

Glass is one of the chemical industry products frequently encountered in daily life. Physically, glass is considered a very cold liquid because its particles remain spaced apart like in a liquid, despite its solid form. This occurs due to the very rapid cooling process, which prevents silica particles from arranging themselves in an orderly manner. From a chemical perspective, glass is a mixture of various inorganic oxides that are not easily volatilized, produced from the decomposition and melting of alkali compounds, alkaline earths, sand, and other materials.



Figure 3. 2 Glass Powder

Glass powder is a material produced from glass itself (glass waste). Lin, et al. (2008) state that glass has the ability to participate in pozzolanic reactions, which enhances the positive characteristics of a mixture. It can be concluded that waste glass powder can be used as a filler material in coarse asphalt concrete mixtures. The chemical element content found in glass can be seen in Table 3.5.

Table 3.5 Glass Content

Glass Type	Clear Glass	Amber Glass	Green Glass	Pyrex Glass	Fused Silica
SiO_2	73,2 – 73,5	71,0 – 72,4	71,27	81	99,87
Al_2O_3	1,7 – 1,9	1,7 – 1,8	2,22	2	-
$Na_2O + K_2O$	13,6 – 14,1	13,8 – 14,4	13,06	4	-
CaO + MgO	10,7 – 10,8	11,6	12,17	-	-
SO_3	0,2 – 0,24	0,12 – 0,14	0,052	-	-
Fe_2O_3	0,04 – 0,05	0,3	0,599	3,72	-
Cr_2O_3	-	0,01	0,43	12,0 – 13,0	-

Source: Setiawan (2006)

Table 3.6 Glass Powder Content

Element	Content (%)
SiO_2	61,72
Al_2O_3	3,45
Fe_2O_3	0,18
CaO	2,59

Source: Hanafiah (2011)

3.4 Asphalt Concrete – Binder Course (AC-BC)

The asphalt concrete layer that serves as the binder material is known as AC-BC. This layer is part of the road surface structure, located between the base course and the wearing course. AC-BC consists of solid and continuous aggregates and is generally used for roads with moderate to heavy traffic. The requirements for AC-BC mixtures can be seen in Table 3.7.

Table 3.7 Mixture Properties of AC

Mixture Properties		Asphalt Concrete		
		Surface layer	Base layer	Foundation
Number of Impacts per Unit Area		75		112
Ratio of Particles Passing Through a 0.075 mm Sieve to Effective Asphalt Content	Min.	0,6		
	Max.	1,2		
Voids in Mix (%)	Min.	3		
	Max.	5		
Voids in Aggregate (VMA) (%)	Min.	15	14	13
Asphalt Binder Content (%)	Min.	65	65	65
Marshall Stability (kg)	Min.	800		1800
Flow (mm)	Min.	2		3
	Max.	4		6
Residual Marshall Stability (%) after Immersion for 24 Hours at 60°C	Min.	90		
Voids in Mix (%), at Refusal Density	Min.	2		

Source: Bina Marga (2018)

3.5 Batanghari River Water

A river is a long pathway on the Earth's surface that serves as a channel for continuously flowing water in a specific direction. River water can come from various sources, such as groundwater, rainfall, and surface water, and its flow eventually drains into the sea, another river, or an open body of water. Odum (1996) defines a river as a water body with a continuous flow of water in a specific direction, originating from groundwater and surface water, and ultimately flowing into the sea. A characteristic feature of a river's watershed is that, as one moves upstream, the topography becomes increasingly hilly and mountainous. Rivers are public water bodies located on land and function as open ecosystems that are closely connected with terrestrial and lentic systems.

The Batanghari River in Jambi Province is the primary source of raw water for the Jambi City Water Supply Company (PDAM). Various activities along the river, such as agriculture, industry, Angso Duo Market (the main market in Jambi City), mining, and tourism, highlight the importance of paying special attention to the water quality of the Batanghari River to prevent pollution. Wiriani et al., (2018) conducted a study on the sustainable water quality analysis of the Batanghari River in Jambi City. Based on the Pollution Index (PI) calculations from parameters such as TDS, TSS, pH, DO, BOD, COD, PO4, and NO3, it was found that the water quality of the Batanghari River for Class I and Class II uses falls into the moderately polluted category, while for Class III and Class IV uses, it falls into the lightly polluted category.

Several roads in Jambi City near the Batanghari River face issues with water accumulation, particularly due to extreme weather causing flooding. Continuous waterlogging of these roads leads to a reduction in the durability of the pavement layers. According to Sukirman (2003), waterlogging causes the subgrade layers in road construction to become saturated. When flooding immerses the pavement layers, they become worn and damaged. This waterlogging allows water to infiltrate the pavement layers, causing the asphalt to become brittle due to water exposure. This brittleness reduces the asphalt's bond strength with the aggregate,

allowing the aggregate to detach from the asphalt and leading to the formation of potholes, which decreases the strength and durability of the road.

3.6 River Water Test

This study evaluates two primary water quality parameters: turbidity and pH. Turbidity represents the degree of water cloudiness caused by suspended particles and is expressed in Nephelometric Turbidity Units (NTU). According to the World Health Organization, drinking water should ideally have a turbidity of less than 5 NTU. While no specific standards exist for pavement-related contexts, lower turbidity is preferable to limit sediment buildup on pavement surfaces. Elevated turbidity can worsen pavement deterioration by introducing abrasive particles that accelerate surface wear, block the pores of asphalt, reduce permeability, and trap moisture—factors that contribute to stripping and material breakdown. Meanwhile, pH indicates the acidity or alkalinity of water on a scale from 0 to 14, with 7 being neutral. For pavement applications, water with a pH between 6.5 and 8.5 is generally considered safe, as values outside this range may chemically interact with asphalt binders. Acidic water ($pH < 6.5$) can weaken the bond between binder and aggregate, increasing the risk of adhesion failure, while highly alkaline water ($pH > 8.5$) can lead to binder emulsification, thereby reducing the cohesion of the pavement.

3.7 Marshall Test Parameter

The Marshall test is a testing method that uses the Marshall apparatus to measure several parameters, including Stability, Flow, Void in the Total Mix (VITM), Void Filled With Asphalt (VFWA), Void in Mineral Aggregate (VMA), Density, and Marshall Quotient.

3.6.1 Stability

Stability refers to the ability of an asphalt concrete mix to withstand loads until the mix experiences plastic deformation. Stability increases with the amount of asphalt up to an optimal point, and then decreases once that point is exceeded. However, excessively high stability values are also not ideal, as they can make the pavement rigid and brittle. The stability value can be calculated using Equation

3.1, and the graph showing the relationship between asphalt content and stability value can be seen in Figure 3.2 below.

$q = p \times s$ (3.1)

Description :

q = Stability Value,

p = stability gauge reading x tool calibration, and

s = Correction value for sample thickness.

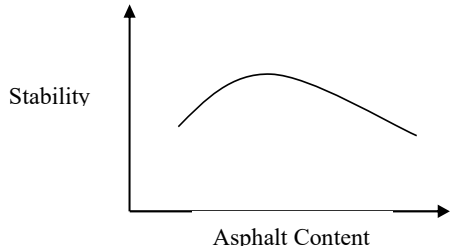


Figure 3.3 Relationship Between Asphalt Content and Stability Value

(Source: Sukirman, 1993)

3.6.2 Flow

Flow is the condition where the asphalt mix undergoes deformation due to the loads it bears. The flow value is influenced by the asphalt content and viscosity, aggregate gradation, and the compaction process. The flow value increases with higher asphalt content, as a thicker asphalt coating reduces friction between the aggregates.

The flow value is obtained from the flow gauge reading during the Marshall Test, measured in millimeters (mm). The graph showing the relationship between asphalt content and flow value can be seen in Figure 3.3 below.

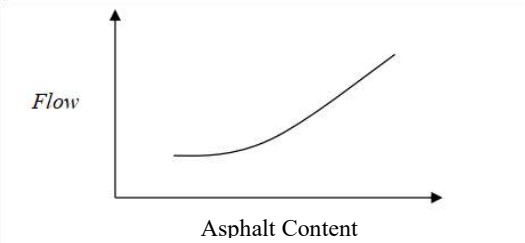


Figure 3.4 Relationship Between Asphalt Content and Flow

(Source: Sukirman, 1993)

3.6.3 Density

The density value is a measure of the weight-to-volume ratio, indicating the compactness of the asphalt aggregate mix. A mix with a high density value can better withstand loads because the voids within the mix are smaller, and the aggregate particles have a larger contact area. This increases the friction between particles and makes the mix more resistant to air and water, thereby reducing the risk of oxidation. The density value and graph can be calculated using Equations 3.2 and 3.3 and can be seen in Figure 3.4 below.

$$g = \frac{c}{f} \tag{3.2}$$

$$f = d - e \tag{3.3}$$

description :

g = density value (gr/cc),

c = sample weight before soaked (gr),

d = sample weight in saturated condition / SSD (gr),

e = weight in water (gr), and

f = volume (cm^3).

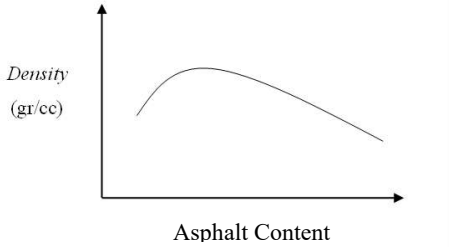


Figure 3.5 Relationship Between Asphalt Content and Density

(Source : Sukirman, 1993)

3.6.4 VMA (Void in Mineral Aggregate)

VMA (Void in Mineral Aggregate) is the percentage of air voids present between aggregate particles in a compacted asphalt mix. VMA represents the space available to accommodate asphalt and the voids required in the mix. Factors affecting VMA values include aggregate gradation (the composition of the aggregate mix and the largest particle diameter), asphalt content, aggregate

texture, and the water absorption capacity of the aggregate. VMA values can be calculated using Equations 3.4 and 3.5 below.

$$l = 100 - \text{j} \tag{3.4}$$

$$\text{j} = \frac{(100-b)\times \text{g}}{BJ\ A\text{ggregate}} \tag{3.5}$$

description :

l = VMA value (%),

b = asphalt content percentage in mixture (%), and

g = bulk weight of sample (gr/cc).

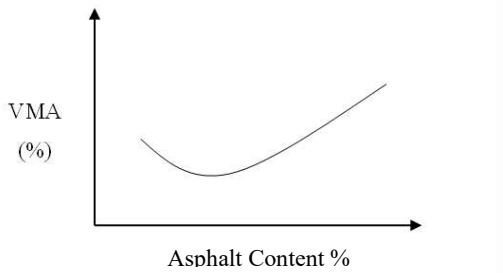


Figure 3.6 Relationship Between Asphalt Content and VMA

(Source : Sukirman, 1992)

3.6.5 VITM (Void in Total Mix)

VITM (Void in the Total Mix) is the percentage of air voids relative to the total volume of the mix after compaction. If the VITM value meets the standards, the asphalt mix will have good resistance to plastic deformation. However, if the VITM value is too high, the mix becomes porous, allowing water and air to easily enter, which can lead to oxidation and plastic deformation in the asphalt mix. Conversely, a VITM value that is too low can cause instability and plastic flow. The VITM value can be calculated using Equations 3.6 and 3.7, and the graph showing the relationship between asphalt content and VITM value can be seen in Figure 3.6 below.

$$n = 100 - \left(100 - \frac{g}{h}\right) \tag{3.6}$$

$$h = 100 - \left(\frac{100}{\left(\frac{\%\ Aggregate}{BJ\ Aggregate} + \frac{\%\ Asphalt}{Bj\ Asphalt}\right)}\right) \tag{3.7}$$

description :

n = VITM value,

g = bulk weight of sample (gr/cc), and

h = Maximum sample theoretical specific gravity.

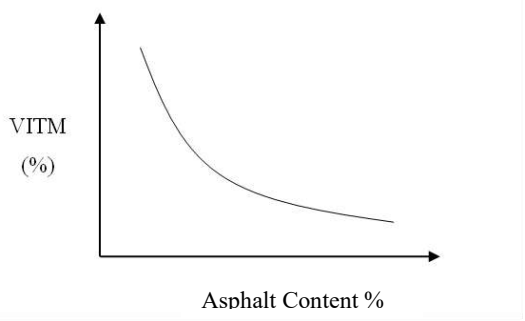


Figure 3.7 Relationship Between Asphalt Content and VITM

(Source : Sukirman, 1993)

3.6.6 VFWA (Void Filled With Asphalt)

VFWA (Void Filled With Asphalt) is the percentage of voids in the mix that are filled with asphalt, which increases with higher asphalt content until reaching an optimal point where the voids are fully occupied. As the VFWA value increases, more asphalt fills the voids, enhancing the mix's resistance to water and air. Conversely, a low VFWA value reduces the pavement's impermeability, making the asphalt more susceptible to oxidation and decreasing its durability.

The VFWA value can be obtained from Equations 3.8 through 3.10, and the graph showing the relationship between asphalt content and VFWA value can be seen in Figure 3.7 below.

1. Asphalt percentage against mixture

$$h = \frac{a}{100+a} \text{ x } 100 \quad (3.8)$$

description :

a = asphalt percentage against terhadap rock, and
b = asphalt percentage against mixture.

2. Asphalt percentage against aggregate

$$m = 100\, x\, \frac{i}{l} \quad (3.9)$$

$$i = \frac{b\, x\, g}{Bj\ Asphalt} \quad (3.10)$$

$$\ell = 100 - j \quad (3.11)$$

$$j = \frac{(100-b)\,x\,g}{Bj\ Aggregate} \quad (3.12)$$

description :

m = VFWA (%),

g = bulk weight of sample(gr/cc), and

b = asphalt percentage agains mixture.

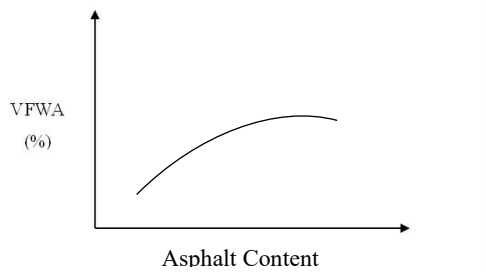


Figure 3.8 Relationship Between Asphalt Content and VFWA

(Source : Sukirman, 1993)

3.6.7 MQ (Marshall Quotient)

Marshall Quotient (MQ) is the ratio between stability and flow. The MQ value reflects the flexibility (or ductility) of the asphalt aggregate mix; a higher MQ value indicates a stiffer mix, while a lower MQ value suggests that the mix is more flexible. Factors affecting the MQ value include elements that also influence stability and flow, such as the shape, quality, surface texture, cohesion, and viscosity of the asphalt. The MQ value can be seen in Equation 3.13 below.

$$\text{MQ} = \frac{q}{r} \quad (3.13)$$

Keterangan :

MQ = Marshall Quotient value,

q = stability value (kg), and

r = flow value (mm).

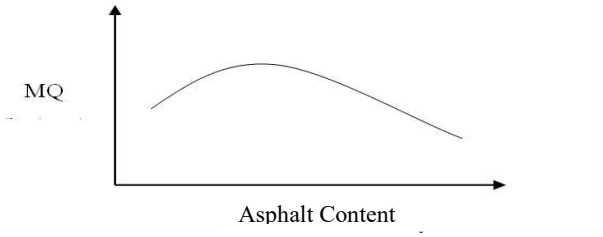


Figure 3.9 Relationship Between Asphalt Content and MQ

(Source : Sukirman, 1993)

3.8 Indirect Tensile Strength (ITS)

Indirect Tensile Strength is a method used to measure the tensile strength of asphalt concrete mixtures. The purpose of this test is to identify the potential for cracking in the field. This test is similar to the Marshall test, but differs in that, in the indirect tensile strength test, a proving ring is not used as the load; instead, a strip loading of 0.5 inches wide is used. The main reasons for choosing the Indirect Tensile Strength test are as follows:

1. This test is relatively simple.
2. The type of sample and equipment used are the same as those for other tests.
3. The damage is not affected by surface conditions.

The Indirect Tensile Strength Test measures the maximum tensile strength, which is calculated from the peak load as shown in Equation 3.13.

$$\text{ITS} = \frac{P\,fall}{h} \text{ x } Ao \qquad (3.13)$$

Keterangan :

ITS = indirect tensile strenght (kg/cm2),

P fall = peak load (kg),

h = sample height (cm), and

Ao = constant (Ao table is attached in the appendix).

3.9 Index of Retained Strength (IRS)

IRS aims to evaluate changes in the characteristics of asphalt mixtures due to the effects of water, temperature, and weather. The result of the Index of Retained Strength (IRS) calculation is the percentage of the stability value of the

mix soaked for 0.5 hours and 24 hours (S2), compared to the stability of the mix that was not soaked (S1). This is explained in Equation 3.14 below.

$$IRS = \frac{S2}{S1} \text{ x } 100\% \quad (3.14)$$

description :

S_1 = stability after soaking for 0.5 hours, and

S_2 = stability after soaking for 24 hours

3.10 Tensile Strength Ratio (TSR)

The TSR value is calculated by comparing the tensile strength of the mix after soaking for 24 hours in a water bath at 60°C with the tensile strength of the mix without soaking, and then multiplying by 100. This calculation is given by Equation 3.15 below.

$$TSR = (T_2/T_1) \text{ x } 100 \quad (3.15)$$

description :

S_1 = average ITS value without soaking, and

S_2 = Average ITS value after 24 hours of soaking (kg).

3.11 Cantabro Test (CL)

The Cantabro Loss test aims to measure the resistance of a specimen to wear using the Los Angeles machine. The purpose of this test is to assess the mix's durability against repeated traffic loads that can cause the pavement to wear out and decrease its strength. The specimen must be allowed to stand for 48 hours at room temperature and maintained at the same temperature for at least 6 hours before testing. Before placing the specimen into the Los Angeles drum, it is weighed to obtain the initial weight before abrasion (Mo). The specimen is then placed into the Los Angeles drum without steel balls, and the machine is operated at a speed of 30-33 rpm for 300 revolutions. After testing, the specimen is removed and weighed to obtain the weight after abrasion (Mi). The weight loss can be calculated using Equation 3.16 below.

$$L = \frac{Mo-Mi}{Mo} \text{ x } 100\% \qquad (3.16)$$

description :

Mo = weight before abrasion(gr),

Mi = weight after abrasion (gr), and

L = weight loss percentage (%).

CHAPTER IV
RESEARCH METHOD

4.1. Research Method

In this study, an experimental research method was employed. This approach involved the creation of a set number of test specimens with specific variables, which were then subjected to testing to obtain data. The collected data were subsequently analyzed to compare them against the standards and requirements set forth by the *SNI* or Bina Marga. The primary objective of this research was to evaluate the effect of immersion in Batanghari River water on the AC-BC pavement mixture with the addition of glass powder as a filler, specifically in relation to Marshall characteristics, Indirect Tensile Strength (ITS), Index of Retained Strength (IRS), Tensile Strength Ratio (TSR), and Cantabro Loss.

4.2. Data Collection Method

The data collection in this study is categorized as primary data obtained during the testing process. To facilitate the collection process, the data were grouped based on the type of test specimens, encompassing information on stability, flow, density, Marshall Quotient, Void in Total Mix (VITM), Void in Mineral Aggregate (VMA), Void Filled with Asphalt (VFWA), Indirect Tensile Strength (ITS), Index of Retained Strength (IRS), Tensile Strength Ratio (TSR), and the results of the Cantabro Loss test.

4.3. Research Stage

This research involved several stages of testing and the determination of asphalt content to achieve a design outcome that meets the applicable standards and regulations.

4.3.1 Material Preparation and Inspection

The examination of research materials was conducted to assess their suitability based on the specifications used. The specified values referenced AASHTO, *SNI* 8129:2015, and the 2018 Bina Marga General Specifications. The materials tested for the AC-BC mixture included aggregate, asphalt, and filler. The tests conducted on the aggregate and asphalt are as follows.

1. Aggregate Test
    a. Coarse Aggregate Specific Gravity and Water Absorption Testing, Conducted in accordance with *SNI* 1969:2016, this test aims to determine the apparent specific gravity, bulk specific gravity, saturated surface-dry (SSD) specific gravity, and water absorption values.
    b. Fine Aggregate Specific Gravity and Water Absorption Testing, Following *SNI* 1970:2016, this test aims to determine the apparent specific gravity, bulk specific gravity, saturated surface-dry (SSD) specific gravity, and water absorption values.
    c. Aggregate-Asphalt Adhesion Testing, conducted in accordance with *SNI* 2439:2011, this test aims to evaluate the adhesion level between the aggregate and the asphalt.
    d. Sand Equivalent Testing, in accordance with *SNI* 03-4428-1997, this test aims to determine the content of clay, dust, or silt in the fine aggregate.
    e. Los Angeles Abrasion Testing ,conducted in accordance with *SNI* 2417:2008, this test aims to assess the durability of coarse aggregates by evaluating their resistance to abrasion using the Los Angeles machine.
    f. Sieve Analysis Testing, following *SNI* ASTM C136-2012, this test uses a set of sieves to determine the gradation of coarse aggregate, fine aggregate, and filler.
2. Asphalt Test

Asphalt functions as a binding material between aggregates in pavement mixtures. In this study, AC 60/70 asphalt was used as the binding material. The tests conducted to determine the quality of the asphalt are as follows.

a. Asphalt Specific Gravity Testing conducted in accordance with *SNI* 2441:2011, this test aims to determine the specific gravity of the asphalt to be used.
b. Ductility Testing, following *SNI* 2432:2011, this test aims to assess the cohesion and flexibility of the asphalt. The test is conducted at 25°C by placing asphalt in two different molds, then pulling the asphalt at a rate of 50 mm/min and measuring the maximum length of the asphalt before it breaks, which allows for the determination of its ductility value.
c. Penetration Testing, in accordance with *SNI* 2456:2011, this test is conducted to determine the hardness of the bitumen using a 0.1 mm needle under specific load, time, and temperature conditions.
d. Solubility Testing in Trichloroethylene (TCE), conducted according to ASTM D2042, this test aims to determine the solubility level of the asphalt using a TCE solution, which indicates the purity of the asphalt.
e. Flash and Fire Point Testing, following *SNI* 2433:2011, this test is conducted to determine the temperature at which the asphalt briefly ignites on its surface (flash point) and the temperature at which the asphalt burns for approximately 5 seconds at a specific point (fire point).
f. Softening Point Testing, in accordance with *SNI* 2434:2011, this test aims to determine the softening point of the asphalt, with values typically ranging between 30°C and 200°C.

3. Filler Test

Filler is a fine-grained material that serves as a filler in asphalt mixtures. It is defined as the mineral dust fraction that passes through a No. 200 sieve (0.074 mm). Filler testing must meet the requirements specified in *SNI* 03-6723-2002.

4.3.2 Equipment Preparation

The equipment supporting this research was provided by the Highway Laboratory, Department of Civil Engineering, Faculty of Civil Engineering and Planning, Universitas Islam Indonesia. The equipment used is as follows.

1. A set of aggregate testing equipment, including a sieve analysis set, Los Angeles machine, sand equivalent tube, and vibrator.

2. A set of asphalt testing equipment, including devices for ductility, penetration, asphalt solubility, flash point, fire point, and softening point.
3. Test molds with a diameter of 10 cm and a height of 7,5 cm.
4. Marshall testing equipment as follows:
   a. A testing ring with a capacity of 2500 kg and an accuracy of 12,5 kg.
   b. A curved platen (breaking head).
   c. A pressure gauge with an accuracy of 0,0025 cm.
   d. A flow indicator gauge with an accuracy of 0,25 mm, along with its accessories.
5. A testing compactor with a weight of 4.536 kg and a drop height of 45,7 cm.
6. An ejector for removing test specimens from molds.
7. A scale with a capacity of 2 kg and an accuracy of 0,1 g, and a scale with a capacity of 5 kg and an accuracy of 1 g, both equipped with hooks.
8. A water bath used for immersing test specimens before testing, equipped with a temperature control set to a minimum of 20°C.
9. An oven used for heating test specimens, with a temperature control set to (200±3) °C. The ITS and TSR testing equipment are as follows.
   a. A compression gauge with a width of 0,5 inches.
   b. A stability and flow gauge with an accuracy of 0,25 mm.
   c. Additional supporting equipment for the research process, including a stove, thermometer, spatula, pan, graduated cylinder, tray, plastic containers, cloths, calipers, and other items.

4.3.3 Mixture Plan

The components of the mixture include coarse aggregate, fine aggregate, filler, and asphalt. The gradation selection is based on three different mixture specifications, namely AC-BC, in accordance with the Bina Marga 2018 Revision 2 guidelines. The gradation design for the AC-BC mixture is presented in Table 4.1 and Figure 4.1 below.

Table 4.1 Gradation Plan for AC-BC Mixture

no	Sieve size			Specification		Gradation plan (%)	
				Min	Max	Passed	Detained
1	1"	25,00	mm	100,00	100,00	100,00	0,00
2	3/4"	19,00	mm	90,00	100,00	95,00	5,00
3	1/2"	12,50	mm	75,00	90,00	82,50	17,50
4	3/8"	9,50	mm	66,00	82,00	74,00	26,00
5	No.4	4,75	mm	46,00	64,00	55,00	45,00
6	No. 8	2,36	mm	30,00	49,00	39,50	60,50
7	No.16	1,18	mm	18,00	38,00	28,00	72,00
8	No.30	0,60	mm	12,00	28,00	20,00	80,00
9	No.50	0,30	mm	7,00	20,00	13,50	86,50
10	No.100	0,15	mm	5,00	13,00	9,00	91,00
11	No.200	0,08	mm	4,00	8,00	6,00	94,00

Source : Bina Marga (2018)

The gradation plan graph used for the AC-BC mixture can be seen in Figure 4.1 below.

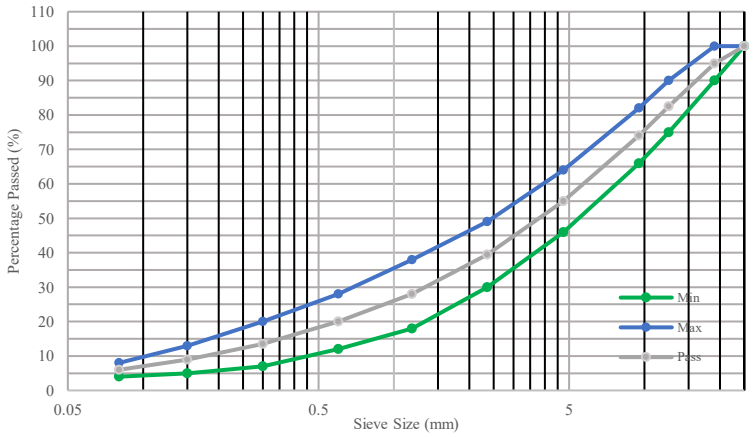


Figure 4.1 Graphics of AC-BC Mixture Gradation

After the aggregate gradation planning stage, the next step is to determine the optimum asphalt content (*KAO*) for the design. The calculation of the optimum asphalt content can be seen in Equation 4.1 below.

$$Pb = 0{,}035 \text{ x } (\%CA) + 0{,}045 \text{ x } (\%FA) + 0{,}18\ (\%Filler) + K \qquad (4.1)$$

description :

Pb = Estimated asphalt content,

CA = Coarse aggregate retained by sieve No. 4,

FA = Fine aggregate passing sieve No. 4 and retained by No. 200,

Filler = Fine aggregate passing sieve No. 200, and

K = Constant 0.5 – 1 for Asphalt Concrete Layer (*LASTON*)

From the results of Equation 4.1, the optimum asphalt content value is obtained as follows:

Pb = 0,035 x (%CA) + 0,045 x (%FA) + 0,18 (%Filler) + K

Pb = 0,035 x (45%) + 0,045 x (49%) + 0,18 (6%) + 1

Pb = 5,86 %

From the calculations above, the estimated optimum asphalt content is 5,86% mark up to 6%. For valid precision in the design, OAC testing will use asphalt contents of 5%, 5,5%, 6%, 6,5%, and 7% relative to the total mixture weight. The details of the aggregate requirements for each asphalt content are presented in Tables 4.2 through 4.6.

Table 4.2 Aggregate Requirements for 5% Asphalt Content

Sieve Size		**Spesification**		**Aggregate Percentage (%)**		**Retained weight (Gr)**	
Inch	**mm**	**Min**	**Max**	**Passed**	**Retained**	**Retained**	**Total**
1"	25,00	100,00	100,00	100,00	0,00	0	0
3/4"	19,00	90,00	100,00	95,00	5,00	57	57
1/2"	12,50	75,00	90,00	82,50	17,50	142,5	199,5
3/8"	9,50	66,00	82,00	74,00	26,00	96,9	296,4
No.4	4,75	46,00	64,00	55,00	45,00	216,6	513
No. 8	2,36	30,00	49,00	39,50	60,50	176,7	689,7
No.16	1,18	18,00	38,00	28,00	72,00	131,1	820,8
No.30	0,60	12,00	28,00	20,00	80,00	91,2	912
No.50	0,30	7,00	20,00	13,50	86,50	74,1	986,1
No.100	0,15	5,00	13,00	9,00	91,00	51,3	1037,4
No.200	0,08	4,00	8,00	6,00	94,00	34,2	1071,6
Pan		0	0	0	6	68,4	1140
Total							1140

Table 4.3 Aggregate Requirements for 5,5% Asphalt Content

Sieve Size		Spesification		Aggregate Percentage (%)		Retained weight (Gr)	
Inch	**mm**	**Min**	**Max**	**Passed**	**Retained**	**Retained**	**Total**
1"	25,00	100,00	100,00	100,00	0,00	0	0
3/4"	19,00	90,00	100,00	95,00	5,00	56,7	56,7
1/2"	12,50	75,00	90,00	82,50	17,50	141,75	198,45
3/8"	9,50	66,00	82,00	74,00	26,00	96,39	294,84
No.4	4,75	46,00	64,00	55,00	45,00	215,46	510,3
No. 8	2,36	30,00	49,00	39,50	60,50	175,77	686,07
No.16	1,18	18,00	38,00	28,00	72,00	130,41	816,48
No.30	0,60	12,00	28,00	20,00	80,00	90,72	907,2
No.50	0,30	7,00	20,00	13,50	86,50	73,71	980,91
No.100	0,15	5,00	13,00	9,00	91,00	51,03	1031,94
No.200	0,08	4,00	8,00	6,00	94,00	34,02	1065,96
Pan		0	0	0	6	68,04	1065,96
Total							1134

Table 4.4 Aggregate Requirements for 6% Asphalt Content

Sieve Size		Spesification		Aggregate Percentage (%)		Retained weight (Gr)	
Inch	**mm**	**Min**	**Max**	**Passed**	**Retained**	**Retained**	**Total**
1"	25,00	100,00	100,00	100,00	0,00	0	0
3/4"	19,00	90,00	100,00	95,00	5,00	56,4	56,4
1/2"	12,50	75,00	90,00	82,50	17,50	141	197,4
3/8"	9,50	66,00	82,00	74,00	26,00	95,88	293,28
No.4	4,75	46,00	64,00	55,00	45,00	214,32	507,6
No. 8	2,36	30,00	49,00	39,50	60,50	174,84	682,44
No.16	1,18	18,00	38,00	28,00	72,00	129,72	812,16
No.30	0,60	12,00	28,00	20,00	80,00	90,24	902,4
No.50	0,30	7,00	20,00	13,50	86,50	73,32	975,72
No.100	0,15	5,00	13,00	9,00	91,00	50,76	1026,48
No.200	0,08	4,00	8,00	6,00	94,00	33,84	1060,32
Pan		0	0	0	6	67,68	1128
Total							1128

Table 4.5 Aggregate Requirements for 6,5% Asphalt Content

Sieve Size		Spesification		Aggregate Percentage (%)		Retained weight (Gr)	
Inch	**mm**	**Min**	**Max**	**Passed**	**Retained**	**Retained**	**Total**
1"	25,00	100,00	100,00	100,00	0,00	0	0
3/4"	19,00	90,00	100,00	95,00	5,00	56,1	56,1
1/2"	12,50	75,00	90,00	82,50	17,50	140,25	196,35
3/8"	9,50	66,00	82,00	74,00	26,00	95,37	291,72
No.4	4,75	46,00	64,00	55,00	45,00	213,18	504,9
No. 8	2,36	30,00	49,00	39,50	60,50	173,91	678,81
No.16	1,18	18,00	38,00	28,00	72,00	129,03	807,84
No.30	0,60	12,00	28,00	20,00	80,00	89,76	897,6
No.50	0,30	7,00	20,00	13,50	86,50	72,93	970,53
No.100	0,15	5,00	13,00	9,00	91,00	50,49	1021,02
No.200	0,08	4,00	8,00	6,00	94,00	33,66	1054,68
Pan		0	0	0	6	67,32	1122
Total							1122

Table 4.6 Aggregate Requirements for 7% Asphalt Content

Sieve Size		Spesification		Aggregate Percentage (%)		Retained weight (Gr)	
Inch	**mm**	**Min**	**Max**	**Passed**	**Retained**	**Retained**	**Total**
1"	25,00	100,00	100,00	100,00	0,00	0	0
3/4"	19,00	90,00	100,00	95,00	5,00	55,8	55,8
1/2"	12,50	75,00	90,00	82,50	17,50	139,5	195,3
3/8"	9,50	66,00	82,00	74,00	26,00	94,86	290,16
No.4	4,75	46,00	64,00	55,00	45,00	212,04	502,2
No. 8	2,36	30,00	49,00	39,50	60,50	172,98	675,18
No.16	1,18	18,00	38,00	28,00	72,00	128,34	803,52
No.30	0,60	12,00	28,00	20,00	80,00	89,28	892,8
No.50	0,30	7,00	20,00	13,50	86,50	72,54	965,34
No.100	0,15	5,00	13,00	9,00	91,00	50,22	1015,56
No.200	0,08	4,00	8,00	6,00	94,00	33,48	1049,04
Pan		0	0	0	6	66,96	1116
Total							1049,04

The details of the number of sample used to determine the OAC are provided in Table 4.7.

Table 4.7 Number of Sample for Optimum Asphalt Content Testing

Asphalt Type	Number of Sample for Each Asphalt Content (units)				
	5 %	5,5%	6 %	6,5 %	7 %
Pertamina Pen 60/70	3	3	3	3	3
Total	15				

The number of sample for each test, after determining the OAC, can be seen in Table 4.8.

Table 4.8 Number of sample for Each Submersion with a 0-Hour Duration

Testing Type	Number of Sample Based on Submersion Duration (units)				
	0 Hour				
Filler	0%	25%	50%	75%	100%
Marshall	3	3	3	3	3
ITS	3	3	3	3	3
IRS	3	3	3	3	3
TSR	3	3	3	3	3
Cantabro	3	3	3	3	3
Number	15	15	15	15	15
Total	75				

Table 4.9 Number of sample for Each Submersion with a 24-Hour Duration

Testing Type	Number of Sample Based on Submersion Duration (units)				
	24 Hour				
Filler	0%	25%	50%	75%	100%
Marshall	3	3	3	3	3
ITS	3	3	3	3	3
IRS	3	3	3	3	3
TSR	3	3	3	3	3
Cantabro	3	3	3	3	3
Number	15	15	15	15	15
Total	75				

Table 4.10 Number of sample for Each Submersion with a 48-Hour Duration

Testing Type	Number of Sample Based on Submersion Duration (units)				
	48 Hour				
Filler	0%	25%	50%	75%	100%
Marshall	3	3	3	3	3
ITS	3	3	3	3	3
IRS	3	3	3	3	3
TSR	3	3	3	3	3
Cantabro	3	3	3	3	3
Number	15	15	15	15	15
Total	75				

Based on ASTM C-128 when using filler from different sources, it is necessary to adjust calculations based on its specific gravity to ensure the mixture composition remains accurate. In this study, the researcher replaced the stone dust filler with glass powder in various proportions (0%, 25%, 50%, 75%, and 100%). Detailed calculations for OAC gradation plan using these variations in filler can be found in Table 4.11 to 4.15 and equation 4.2

$$\frac{\text{Specific Gravity Glass Powder}}{\text{Specific Gravity Stone Ash}} \text{ x Weight Refference x Filler Proportion \%} \quad (4.2)$$

description :

Weight reference = 100% weight of stone dust filler in gradation plan

$\frac{2,36}{2,54}$ x 67,25 x 25% = 15,60 gr

Based on this calculation, glass powder filler weight in 25% proportion is 15,60. This calculation applies in other proportion.

Table 4.11 Aggregate Necessity with 0% Replacement Filler Content

Sieve Size		Specification (%)		Total Percentage (%)		Retained Weight (gr)	
ASTM	**(mm)**	**Min**	**Max**	**Passed**	**Retained**	**Retained**	**Total**
1"	25	100	100	100	0	0,00	0,00
3/4"	19	90	100	95	5	56,05	56,05
1/2"	12,5	75	90	82,5	17,5	140,12	196,16
3/8"	9,5	66	82	74	26	95,28	291,44
No. 4	4,75	46	64	55	45	212,97	504,41
No. 8	2,36	30	49	39,5	60,5	173,74	678,16
No.16	1,18	18	38	28	72	128,91	807,06

Continuation Table 4.12 Aggregate Necessity with 0% Replacement Filler Content

No. 30	0,6	12	28	20	80	89,67	896,74
No. 50	0,3	7	20	13,5	86,5	72,86	969,60
No. 100	0,15	5	13	9	91	50,44	1020,04
No. 200	0,075	4	8	6	94	33,63	1053,66
Stone Dust Filler						67,25	1120,92
Glass Powder Filler						0,00	1120,92

Table 4.13 Aggregate Necessity with 25% Replacement Filler Content

Sieve Size		Specification (%)		Total Percentage (%)		Retained Weight (gr)	
ASTM	**(mm)**	**Min**	**Max**	**Passed**	**Retained**	**Retained**	**Total**
1"	25	100	100	100	0	0,00	0,00
3/4"	19	90	100	95	5	56,05	56,05
1/2"	12,5	75	90	82,5	17,5	140,12	196,16
3/8"	9,5	66	82	74	26	95,28	291,44
No. 4	4,75	46	64	55	45	212,97	504,41
No. 8	2,36	30	49	39,5	60,5	173,74	678,16
No.16	1,18	18	38	28	72	128,91	807,06
No. 30	0,6	12	28	20	80	89,67	896,74
No. 50	0,3	7	20	13,5	86,5	72,86	969,60
No. 100	0,15	5	13	9	91	50,44	1020,04
No. 200	0,075	4	8	6	94	33,63	1053,66
Stone Dust Filler						50,44	1104,13
Glass Powder Filler						15,60	1119,76

Table 4.14 Aggregate Necessity with 50% Replacement Filler Content

Sieve Size		Specification (%)		Total Percentage (%)		Retained Weight (gr)	
ASTM	**(mm)**	**Min**	**Max**	**Passed**	**Retained**	**Retained**	**Total**
1"	25	100	100	100	0	0,00	0,00
3/4"	19	90	100	95	5	56,05	56,05
1/2"	12,5	75	90	82,5	17,5	140,12	196,16
3/8"	9,5	66	82	74	26	95,28	291,44
No. 4	4,75	46	64	55	45	212,97	504,41
No. 8	2,36	30	49	39,5	60,5	173,74	678,16
No.16	1,18	18	38	28	72	128,91	807,06
No. 30	0,6	12	28	20	80	89,67	896,74
No. 50	0,3	7	20	13,5	86,5	72,86	969,60
No. 100	0,15	5	13	9	91	50,44	1020,04

ContinuationTable 4.15 Aggregate Necessity with 50% Replacement Filler Content

No. 200	0,075	4	8	6	94	33,63	1053,66
Stone Dust Filler						33,63	1087,33
Glass Powder Filler						31,19	1118,62

Table 4.16 Aggregate Necessity with 75% Replacement Filler Content

Sieve Size		Specification (%)		Total Percentage (%)		Retained Weight (gr)	
ASTM	**(mm)**	**Min**	**Max**	**Passed**	**Retained**	**Retained**	**Total**
1"	25	100	100	100	0	0,00	0,00
3/4"	19	90	100	95	5	56,05	56,05
1/2"	12,5	75	90	82,5	17,5	140,12	196,16
3/8"	9,5	66	82	74	26	95,28	291,44
No. 4	4,75	46	64	55	45	212,97	504,41
No. 8	2,36	30	49	39,5	60,5	173,74	678,16
No.16	1,18	18	38	28	72	128,91	807,06
No. 30	0,6	12	28	20	80	89,67	896,74
No. 50	0,3	7	20	13,5	86,5	72,86	969,60
No. 100	0,15	5	13	9	91	50,44	1020,04
No. 200	0,075	4	8	6	94	33,63	1053,66
Stone Dust Filler						16,81	1070,50
Glass Powder Filler						46,79	1117,45

Table 4.17 Aggregate Necessity with 100% Replacement Filler Content

Sieve Size		Specification (%)		Total Percentage (%)		Retained Weight (gr)	
ASTM	**(mm)**	**Min**	**Max**	**Passed**	**Retained**	**Retained**	**Total**
1"	25	100	100	100	0	0,00	0,00
3/4"	19	90	100	95	5	56,05	56,05
1/2"	12,5	75	90	82,5	17,5	140,12	196,16
3/8"	9,5	66	82	74	26	95,28	291,44
No. 4	4,75	46	64	55	45	212,97	504,41
No. 8	2,36	30	49	39,5	60,5	173,74	678,16
No.16	1,18	18	38	28	72	128,91	807,06
No. 30	0,6	12	28	20	80	89,67	896,74
No. 50	0,3	7	20	13,5	86,5	72,86	969,60
No. 100	0,15	5	13	9	91	50,44	1020,04
No. 200	0,075	4	8	6	94	33,63	1053,66
Stone Dust Filler						0,00	1053,66
Glass Powder Filler						62,39	1116,31

4.3.4 Submersion in River Water

In this study, samples will be immersed in Batanghari River water prior to undergoing various tests, with immersion time variations of 0 hours, 24 hours, and 48 hours. These time variations were determined based on the duration of flooding events in various areas of Jambi City caused by the overflow of the Batanghari River. The steps for immersing in river water are as follows.

1. Ensure that the test specimens are free from any dirt or dust.
2. Measure the height of the test specimens at three different points, then calculate the average with an accuracy of up to 0.01 mm.
3. Weigh the test specimens to obtain their dry weight.
4. Immerse the test specimens in river water for varying durations of 24 hours and 48 hours.

4.3.5 Marshall Test

The following are the steps in Marshall testing:

1. Soak the test specimens, which have been removed from the river water, in clean water for approximately 24 hours at room temperature to ensure the specimens are saturated with water.
2. Weigh the test specimens while submerged, then remove them from the water bath and dry the surface of the specimens.
3. Weigh the test specimens in the condition of SSD.
4. Immerse the test specimens in a water bath at ±60°C for 0,5 hours.
5. Clean the guide rod and the guide surface, then lubricate the guide rod so that the test head can move freely.
6. Remove the test specimens from the water bath and place them in the lower segment of the test head.
7. Position the upper segment over the test specimens and place the entire assembly in the testing machine.
8. Set the flow meter to zero, ensuring that the flow meter sleeve is held tightly against the upper segment of the test head. During loading, press the flow meter stem against the upper segment of the test head.

9. Raise the test head along with the test specimens until it contacts the base of the testing ring, then set the pressure gauge to zero.
10. Begin loading at a constant rate of 50 mm/min until reaching the maximum load or until the load decreases as indicated by the pressure gauge. Record the maximum load achieved (stability) and the reading on the flow meter (flow).
11. Release the flow meter sleeve after recording the flow value indicated by the flow meter gauge.
12. Analyze the results and prepare the discussion.

4.3.6 ITS Test

The steps in Indirect Tensile Strength testing are as follows:

1. Place the test specimens, which have been removed from river water immersion, into the ITS testing apparatus for testing.
2. Record the dial readings obtained from the test.
3. Analyze the results and prepare the discussion.

4.3.7 IRS Test

The difference between the standard Marshall test and this test lies in the immersion duration in the water bath, which is 24 hours. The steps for IRS testing are as follows:

1. Prepare the equipment and test specimens to be used.
2. Clean the test specimens of any dirt that may have adhered during the sample preparation process.
3. Measure the height of the test specimens at three sides using calipers, then weigh the specimens in their air-dry condition.
4. Immerse the test specimens in water at room temperature for 20 to 24 hours to achieve saturation, then weigh the specimens while submerged and record the results.
5. Dry the surface of the test specimens that have been weighed in water using a cloth until they reach a SSD condition, then weigh the specimens to obtain their SSD weight.
6. Place the test specimens in a water bath at 60°C for 24 hours.

7. Inspect the Marshall testing machine and its auxiliary dial, and prepare the breaking head that has been lubricated with oil.
8. Remove the test specimens from the water bath and place them in the breaking head, then attach the flow dial and raise the breaking head until the test specimens touch the testing ring.
9. Set the dials for stability and flow to zero.
10. Start the machine and monitor the loading until the stability dial reaches its maximum reading.
11. Analyze the test results and prepare the discussion.

4.3.8 CL Test

The Cantabro Loss test can be performed using the following steps:

1. Prepare the required materials.
2. Weigh the test specimens to determine their weight before the abrasion process (Mo).
3. Place the test specimens in the Los Angeles machine without steel balls.
4. Operate the machine at a speed of 30-33 rpm for 300 revolutions.
5. After the rotation process is complete, remove the test specimens from the machine and weigh them again to obtain their weight after the abrasion test (Mi).

4.4. Data Analysis

After conducting various tests, data analysis is performed to obtain a comprehensive overview of the test parameters..

4.4.1 Marshall Characteristic Test Analysis

The parameters for the Marshall test results are as follows.

1. Dry weight of the test specimen (grams)
2. Weight of the test specimen in water (grams)
3. Weight of the test specimen in SSD condition (grams)
4. Thickness of the test specimen (mm)
5. Stability dial reading (kg)
6. Flow dial reading (mm)

The characteristics of the Marshall test can be calculated using the following equations.

1. Specific Gravity of Asphalt

   The specific gravity of asphalt is calculated using Equation 4.2 as follows.

$$\text{Bj Asphalt} = \frac{C-A}{(B-A)-(D-C)} \quad (4.3)$$

description :

A = weight of the pycnometer with cover (gr)

B = weight of the pycnometer filled with water (gr)

C = weight of the pycnometer filled with asphalt (gr), and

D = weight of the pycnometer filled with both water and asphalt (gr).

2. Specific Gravity of Aggregate

   Berat jenis agregat dihitung dengan menggunakan Persamaan 4.3 berikut ini.

$$\text{Bj Aggregate} = \frac{(A\ x\ F1)+(B\ x\ F2)}{100} \quad (4.4)$$

description :

A = percentage of coarse aggregate (%),

B = percentage of fine aggregate (%),

F1 = specific gravity of coarse aggregate, dan

F2 = specific gravity of fine aggregate.

3. The stability value can be obtained using Equation 3.1.
4. The flow value is obtained from the flow dial reading.
5. The density value can be calculated using Equations 3.2 and 3.3.
6. The VMA value can be determined using Equations 3.4 and 3.5.
7. The VITM value can be calculated using Equations 3.6 to 3.7.
8. The VFWA value can be obtained using Equations 3.8 and 3.12.
9. The MQ value can be calculated using Equation 3.13.

4.4.2 ITS Test Analysis

The Indirect Tensile Strength value can be obtained using Equation 3.14.

4.4.3 IRS Test Analysis

The Index of Retained Strength value can be obtained using Equation 3.15.

4.4.4 TSR Test Analysis

The Tensile Strength Ratio value can be obtained using Equation 3.16.

4.4.5 CL Test Analysis

The Cantabro Loss value can be obtained using Equation 3.17.

4.5. Research Flow Chart

The flow chart provides a summarized depiction of the research stages, illustrated in Figure 4.2 on the subsequent page.

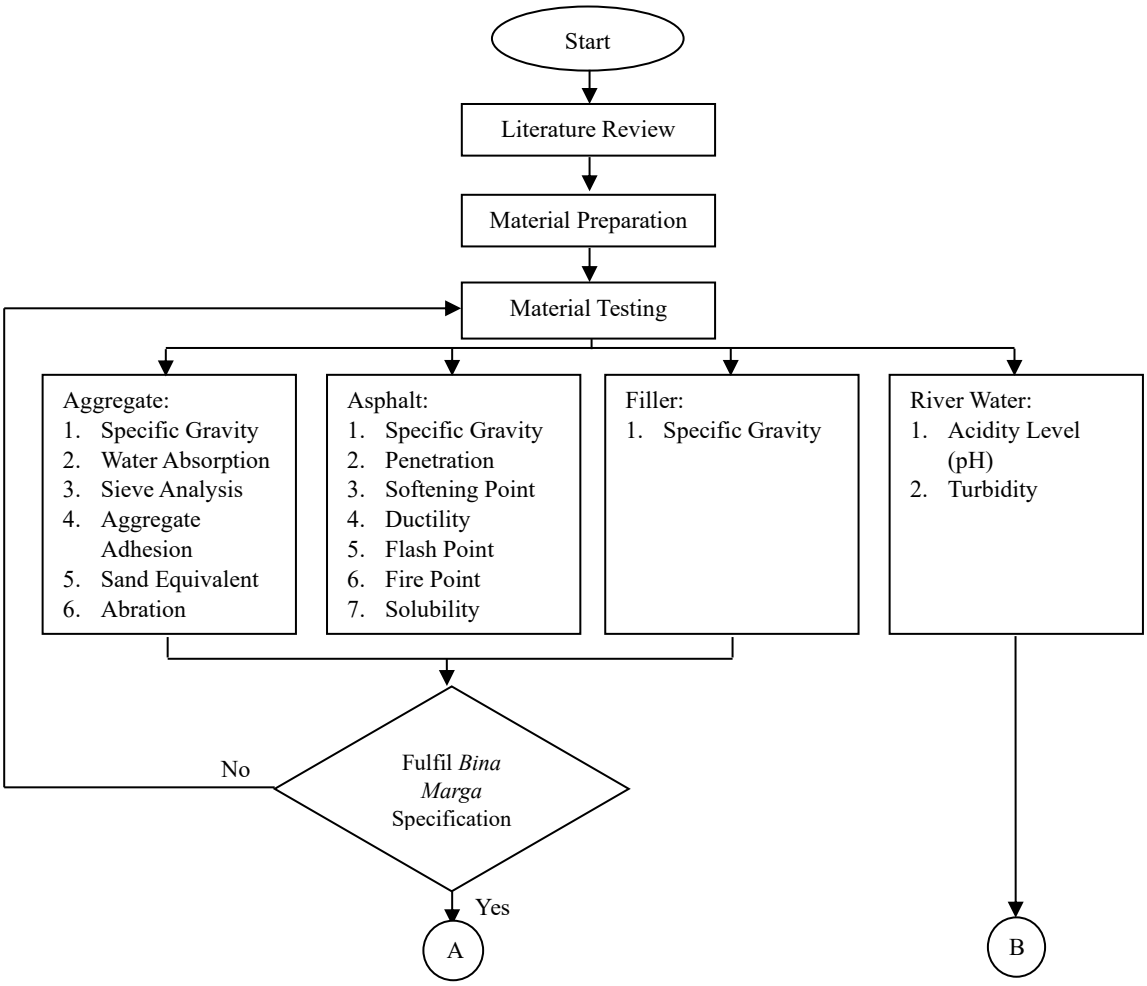
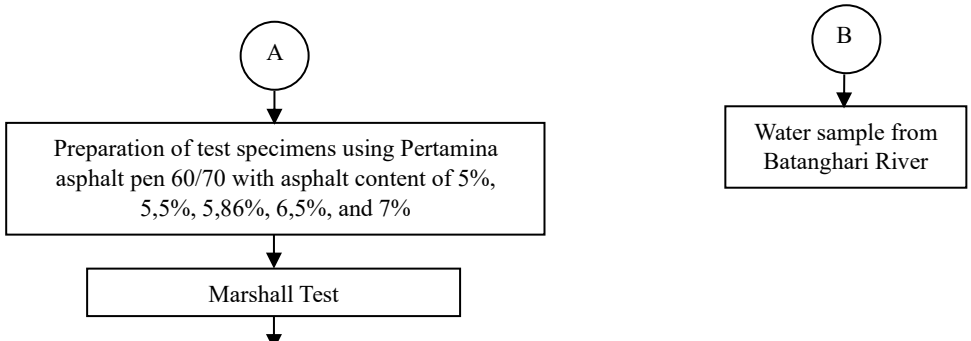
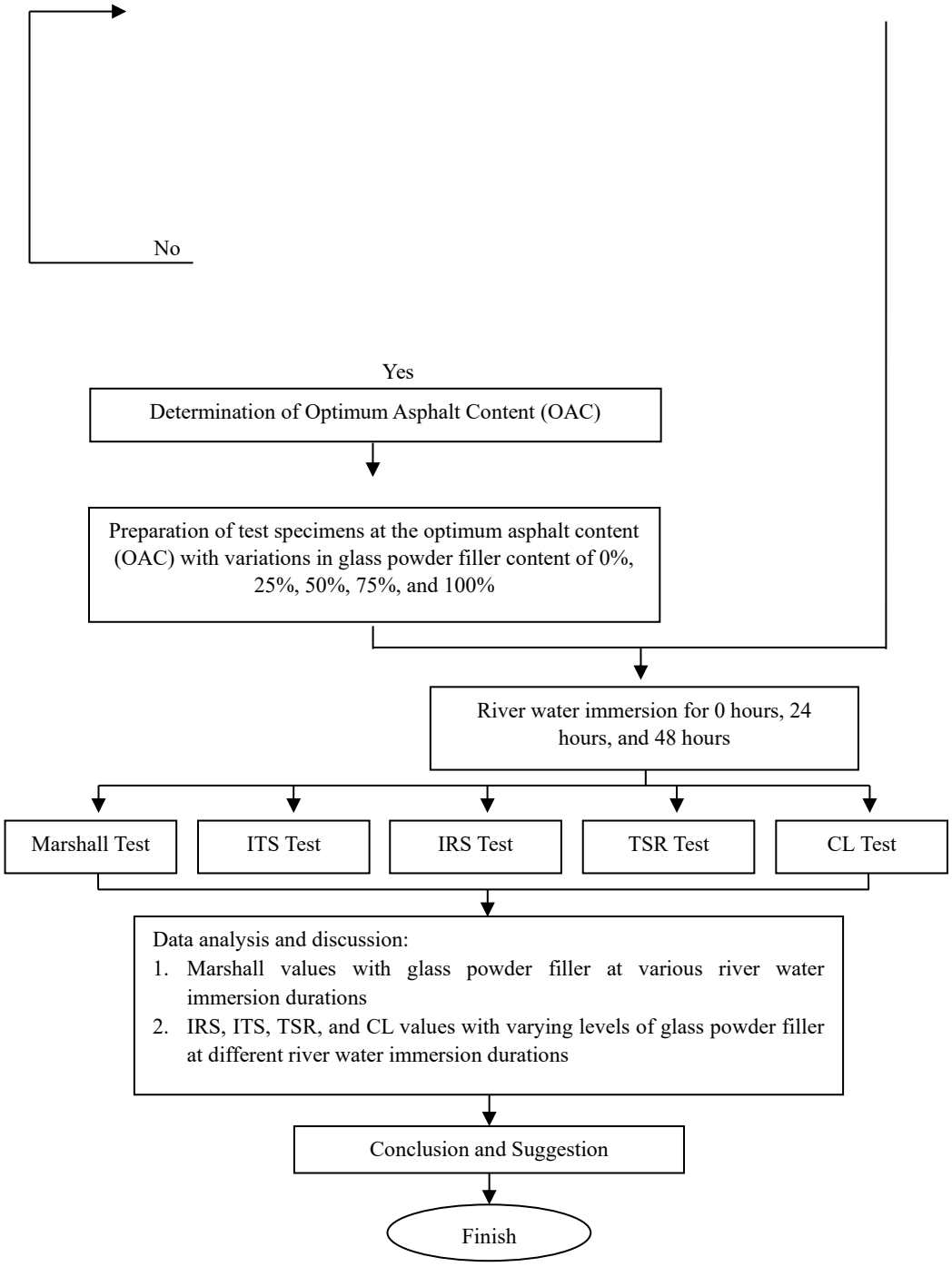


Figure 4.2 Research Flowchart





Continuation Figure 4.2 Research Flowchart

BAB V
ANALYSIS AND DISCUSSION

5.1 Test Result of Material, Mixture and River Water

Based on the conducted series of tests, the findings from each individual test are presented as follows.

5.1.1 Test Result of Ashpalt Characteristics

The testing of asphalt characteristics was carried out at the Highway Laboratory within the Department of Civil Engineering, Faculty of Civil Engineering and Planning, Universitas Islam Indonesia. The tests employed Pen 60/70 asphalt, with the results aligned with the 2018 Bina Marga Specifications, Revision 2. A summary of the obtained test results is presented in Table 5.1 below.

Table 5.1 Result of Pertamina Asphalt Pen 60/70 Test

No	Type of Test	Spesification	Result	Description
1	Specific Gravity	≥ 1,0	1,040	Fullfil
2	Penetration (mm)	60-70	64	Fullfil
3	Ductility (cm)	≥ 100	134,5	Fullfil
4	Softening Point (ºC)	≥ 48	48,5	Fullfil
5	Flash Point (ºC)	≥ 232	308	Fullfil
6	Fire Point (ºC)	≥ 232	313	Fullfil
7	TCE Solubility (%)	≥ 99	99,51	Fullfil

5.1.2 Test Result of Aggregate Characteristics

The aggregate characteristics were evaluated at the Highway Laboratory, Department of Civil Engineering, Faculty of Civil Engineering and Planning, Universitas Islam Indonesia. The aggregates used in this evaluation were sourced from the Clereng River in Kulon Progo, Yogyakarta. The testing process followed the guidelines set forth in the 2018 Bina Marga Specifications, Revision 2. A summary of the results is presented in Tables 5.2 through 5.4 below.

Table 5.2 Result of Coarse Aggregate Test

No.	Type of Test	Spesification	Result
1	Specific Gravity	≥ 2,5	2,57
2	Water Absorption of Aggregate (%)	≤ 3	2,59
3	Aggregate Adhesion to Asphalt (%)	≥ 95	97
4	Wear Aggregate with Los Angeles Machine (%)	≤ 40	12,20

Table 5.3 Result of Clereng Fine Aggregate Test

No.	Type of Test	Spesification	Result
1	Specific Gravity	≥ 2,5	2,65
2	Water Absorption of Aggregate (%)	≤ 2	2,61
3	Sand Equivalent (%)	≥ 50	71,62

Table 5.4 Result of Filler Specific Gravity Test

No.	Type of Test	Result
1	Specific Gravity (Stone Ash)	2,54
2	Specific Gravity (Glass Powder)	2,36

5.1.3 Test Result of River Water Contents

The testing of River Water was carried out at the Environment Quality Laboratory within the Department of Environment Engineering, Faculty of Civil Engineering and Planning, Universitas Islam Indonesia. The tests employed pH and turbidity. A summary of the obtained test results is presented in Table 5.5 below.

Table 5.5 Result of River Water Test

No	Parameter	Unit	Result	Test Method
			APS.007	
1.	Turbidity	NTU	5,44 ± 1,04	SNI 06-6989.25-2005
2.	pH	-	6,54 ± 0,24	SNI 6989.11-2019

5.1.4 Test Result of AC-BC Mixture to Determine Optimum Ashpalt Content

In the testing conducted at the Highway Laboratory of FTSP UII, the Marshall characteristic values were obtained, including stability, flow, VMA VFWA, VITM, MQ, and density from the AC-BC mixture using Pertamina Pen 60/70 asphalt binder.

Table 5.6 Result of Marshall Test to Determine OAC

Recapitulation of Pertamina Asphalt Pen 60/70							
Asphalt Content (%)	**Stability (kg)**	***Flow* (mm)**	***MQ* (kg/mm)**	***VITM* (%)**	***VFWA* (%)**	***VMA* (%)**	**Density (gr/cc)**
5	1044,83	3,28	317,88	7,22	59,91	18,04	2,24
5,5	1103,45	3,38	325,82	6,36	65,17	18,29	2,25
6	1215,28	3,48	348,55	5,35	70,91	18,41	2,26
6,5	1131,26	3,61	313,37	4,70	75,02	18,85	2,26
7	1094,31	3,78	289,24	4,13	78,62	19,35	2,26
Specification	>800	2-4	>250	>3-5	>65	>14	>2

Based on the Marshall test results, the maximum and minimum limits for determining the optimum asphalt content were obtained, shown in the graph Figure 5.1 below.

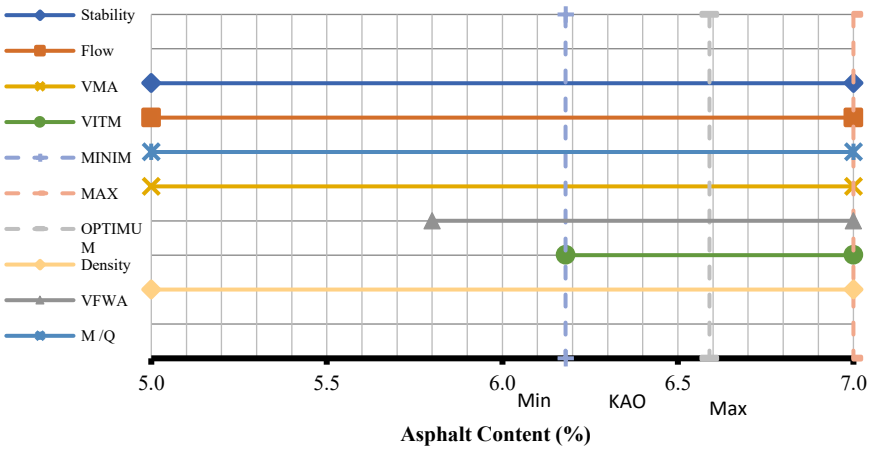


Figure 5.1 Determination of OAC for AC-BC Mixture Using Pertamina Pen 60/70 Asphalt Binder

Based on Figure 5.1 above, the optimum asphalt content used for the AC-BC mixture with Pertamina Pen 60/70 asphalt binder is 6.59%.

5.1.5 Test Result of AC-BC Mixture at Optimum Asphalt Content

After obtaining the OAC value, the next step is to prepare samples using glass powder filler that has been immersed in river water to evaluate its effect on the mixture's performance. The physical characteristics of the glass powder, such as specific gravity and particle shape, need to be analyzed since they influence the mixture's behavior. Test results show that the specific gravity of glass powder is 2,361 g/cm³, which is lower than that of stone dust at 2,544 g/cm³. Figure 5.2 illustrates the morphology of glass powder particles under a microscope, showing the texture and surface shape of the particles. The test is carried out by author with environmental engineering laboratorium help.



Figure 5.2 Glass Powder Particles with 100x Microscope

The AC-BC mixture at the OAC with substituted filler was immersed for 0 hours, 24 hours, and 48 hours. The mixtures were then tested using the Marshall, IRS, ITS, TSR, and CL methods. The test results are presented in Tables 5.7 through 5.11.

Table 5.7 Recapitulation of Marshall Test Results at OAC

Immersion Duration	Filler Content (%)	Stability (kg)	Flow (mm)	MQ (kg/mm)	VITM (%)	VMA (%)	VFWA (%)	Density (gr/cc)
0 Hour	0	1210,99	3,06	396	3,61	18,09	80,03	2,29
	25	1125,96	3,25	346,44	4,08	18,48	78,01	2,27
	50	1140,71	3,10	367,69	3,51	17,98	80,55	2,28
	75	1234,94	3,02	408,54	3,33	17,81	81,33	2,29
	100	1087,63	3,55	306,79	4,33	18,65	76,82	2,26
24 Hour	0	1126,12	3,50	322,02	3,58	18,06	80,19	2,29
	25	1043,62	3,65	285,62	4,18	18,56	77,56	2,27
	50	1069,65	3,45	310,03	3,47	17,95	80,68	2,28
	75	1148,52	3,35	342,79	3,33	17,81	81,35	2,29
	100	1008,49	3,89	259,25	4,27	18,60	77,05	2,26
48 Hour	0	1033,78	3,94	262,44	3,61	18,09	80,22	2,29
	25	982,15	4,13	237,74	4,12	18,51	77,80	2,27
	50	1004,65	3,83	263,41	3,57	18,03	80,21	2,28
	75	1054,43	3,67	288,14	3,29	17,78	81,49	2,29
	100	911,92	4,27	215,98	4,35	18,67	76,68	2,26
Spesification		> 800	2-4	3-5	>14	>250	>68	>2

Table 5.8 Recapitulation of IRS Results at OAC

Immersion Duration	Filler Substitution Content (%)	IRS (%)
0 Hour	0	95,73
	25	95,21
	50	94,89
	75	94,31
	100	93,85
24 Hour	0	93,56
	25	92,98
	50	92,40

Continuation Table 5.8 Recapitulation of IRS Results at OAC

Immersion Duration	Filler Substitution Content (%)	IRS (%)
24 Hour	75	92,07
	100	91,47
48 Hour	0	91,62
	25	91,26
	50	90,76
	75	90,22
	100	89,71

Table 5.9 Recapitulation of ITS Results at OAC

Immersion Duration	Filler Substitution Content (%)	ITS (kPa)
0 Hour	0	148,74
	25	139,77
	50	143,28
	75	149,09
	100	126,00
24 Hour	0	137,13
	25	127,50
	50	130,46
	75	138,03
	100	116,44
48 Hour	0	122,57
	25	116,05
	50	121,45
	75	124,80
	100	104,32

Table 5.10 Recapitulation of TSR Results at OAC

Immersion Duration	Filler Substitution Content (%)	TSR (%)
0 Hour	0	88,27
	25	87,32
	50	86,39
	75	84,49
	100	80,55
24 Hour	0	85,31
	25	84,16
	50	82,85
	75	80,83
	100	77,20

Continuation Table 5.10 Recapitulation of TSR Results at OAC

Immersion Duration	Filler Substitution Content (%)	TSR (%)
48 Hour	0	83,28
	25	81,76
	50	80,09
	75	78,57
	100	75,37

Table 5.11 Recapitulation of CL Results at OAC

Immersion Duration	Filler Substitution Content (%)	*Cantabro Loss* (%)
0 Hour	0	2,74
	25	3,24
	50	3,03
	75	2,75
	100	3,76
24 Hour	0	3,16
	25	3,64
	50	3,44
	75	3,16
	100	4,18
48 Hour	0	3,52
	25	4,03
	50	3,80
	75	3,64
	100	4,74

5.2 Discussion

The discussion of the analysis results from the conducted tests, both on material characteristics and mixture performance, is presented as follows:

5.2.1 Characteristics of the Components of a Mixture and the Contents of River Water

1. The discussion of the test on the characteristics of Pertamina Pen 60/70 asphalt is as follows.
   a. Specific Gravity of Asphalt

      The specific gravity of asphalt is the ratio between the mass of asphalt and the mass of distilled water (aquadest) of the same volume at a given

temperature. Based on laboratory test results, Pertamina Pen 60/70 asphalt has a specific gravity of 1,040. This value indicates that the asphalt meets the specification standards set by Bina Marga 2018 Revision 2, which requires asphalt to have a specific gravity greater than 1.00.

b. Asphalt Penetration

This test was conducted to evaluate the hardness level of bitumen by measuring the penetration of a standard needle under certain temperature conditions, which reflects the consistency properties of the asphalt material. Based on the test results, Pertamina Pen 60/70 asphalt has a penetration value of 66,50 mm. This value shows that the asphalt complies with the quality standards specified in Bina Marga 2018 Revision 2, which requires penetration values to fall within the range of 60 to 70 mm.

c. Ductility of Asphalt

This test aimed to evaluate the cohesive properties of asphalt by measuring the maximum elongation of bitumen before breaking under specific test conditions, which reflects the asphalt's ability to resist deformation and maintain flexibility. Based on the test results, Pertamina Pen 60/70 asphalt has a ductility value of 134,5 cm. This value indicates that the asphalt meets the requirements of Bina Marga 2018 Revision 2, which specifies that ductility must be greater than 100 cm.

d. Fire and Flash Point of Asphalt

This test was carried out to determine the maximum safe temperature for heating asphalt without causing combustion, by measuring the flash point—the temperature at which asphalt vapors can ignite momentarily—and the fire point—the temperature at which asphalt can sustain combustion for at least 5 seconds. The test results for Pertamina Pen 60/70 asphalt showed a flash point of 308°C and a fire point of 312°C. Both values far exceed the minimum requirements specified in Bina Marga 2018 Revision 2, which state that flash point and fire point

temperatures must be ≥ 232°C

e. Softening Point of Asphalt

This test was conducted to determine the temperature at which asphalt begins to soften, which is an important indicator for evaluating the asphalt's resistance to heat-induced deformation in road applications. Based on the test results, Pertamina Pen 60/70 asphalt has a softening point of 48°C. This value meets the requirements of Bina Marga 2018 Revision 2, which specifies a minimum softening point of ≥ 48°C

f. TCE Solubility

This test aimed to determine the content of other minerals in the asphalt by dissolving it with carbon tetrachloride. A higher percentage of solubility indicates a lower content of other minerals that could interfere with the bond between asphalt and aggregate. The test results show that the solubility of Pertamina Pen 60/70 asphalt in TCE reached 99,51%, meeting the Bina Marga 2018 Revision 2 specification requirement of ≥ 99% solubility.

2. The discussion regarding the testing of coarse aggregate properties used in the preparation of test specimens is described as follows.

a. Specific Gravity of Aggregate

Specific gravity is defined as the ratio between the weight of the aggregate in dry condition and the weight of distilled water of the same volume at a certain temperature. This value influences the number of pores in the aggregate, where the higher the specific gravity, the fewer pores are formed, thereby reducing asphalt demand. Based on the test results, Clereng coarse aggregate has a specific gravity of 2,57, which meets the requirements of the 2018 Bina Marga Specifications Revision 2, > 2,5.

b. Water Absorption of Aggregate

Water absorption of aggregates is measured as the percentage of water absorbed by the aggregate pores compared to the weight of the aggregate in dry condition. Aggregates with small pores usually have low water

absorption, thus requiring less asphalt, while aggregates with larger pores require more asphalt. The test results showed that the water absorption of Clereng coarse aggregate was 2,59%, which meets the maximum limit of 3% according to the 2018 Bina Marga Specifications Revision 2.

c. Aggregate Adhesion to Asphalt

Aggregate adhesion to asphalt is defined as the percentage of the aggregate surface area coated with asphalt compared to the total surface area of the aggregate. Based on the test results, the adhesion of aggregates to Pertamina Pen 60/70 asphalt reached 96%. This value meets the requirements of the 2018 Bina Marga Specifications Revision 2, which requires adhesion > 95%.

d. Wear Aggregate with Los Angeles Machine

This test aims to evaluate the resistance of coarse aggregates to degradation due to impact forces using the Los Angeles machine. The abrasion value is calculated as the ratio between the weight of the aggregate abraded and passing through the No. 12 sieve compared to the initial weight of the test sample. The test results showed an abrasion value of 12,20%, which meets the requirements of the 2018 Bina Marga General Specifications Revision 2, less than 40%.

3. The discussion regarding the testing of fine aggregate characteristics used in the preparation of test specimens is described as follows.

a. Spesific Gravity of Asphalt

Specific gravity is defined as the ratio between the weight of a material at a certain volume and the weight of water at the same volume and temperature. Based on the test results, the specific gravity of Clereng fine aggregate reached 2,65, which meets the requirements of the 2018 Bina Marga General Specifications Revision 2, greater than 2,5.

b. Water Absorption of Aggregate

Water absorption of aggregates refers to the ability or degree of a material to absorb water into the voids or pores within the aggregate. Aggregates with high porosity tend to have high water absorption values,

thereby requiring a larger amount of asphalt. Based on the test results, the water absorption of Clereng fine aggregate reached 2,61%. This value satisfies the requirements of the 2018 Bina Marga General Specifications Revision 2, which stipulates a maximum water absorption of less than 3%.

c. Sand Equivalent

This test was conducted to measure the content of dust, silt, or clay materials mixed within the fine aggregates. Fine aggregates free from such contaminants can improve the bonding strength between aggregate and asphalt. The test results showed a value of 71,62%, which meets the requirements of the 2018 Bina Marga General Specifications Revision 2, namely greater than 50%.

4. The discussion regarding the testing of filler characteristics used in the preparation of test specimens is described as follows.

a. Specific Gravity of Stone Dust Testing

Specific gravity is defined as the ratio between the weight of filler in dry condition and the weight of water at the same volume and temperature. The specific gravity value affects the number of pores in the filler, where the higher the specific gravity, the fewer pores exist in the filler particles, and vice versa. Based on the test results, the specific gravity of stone dust was 2,544.

b. Specific Gravity of Glass Powder Testing

Specific gravity is defined as the ratio between the weight of a material and the weight of water at the same volume and temperature. Based on the test results, the specific gravity of glass powder was 2,361.

The specific gravity test was conducted to calculate the volume ratio between stone dust and glass powder in order to ensure volume equivalence. Since the specific gravity of glass powder is lower than that of stone dust filler, at an identical volume, the volume of glass powder will be greater than that of stone dust.

5. The discussion regarding the testing of river water used for soaking the specimens is described as follows.

   Surface water samples were taken from the Batanghari River, located in Jambi City, Jambi Province. The samples were then tested at the Environmental Quality Laboratory, Faculty of Civil Engineering and Planning, Islamic University of Indonesia, with testing parameters including turbidity and pH. The following presents the discussion of the river water quality test results.

   a. Turbidity

      The turbidity test aims to measure the cloudiness of water caused by the presence of fine suspended particles, in order to evaluate the clarity and visual quality of the water. The higher the turbidity value, the greater the particle content in the water, which may interfere with the performance of asphalt mixtures. Based on the test results, the turbidity of Batanghari River water was recorded at 5,44 NTU.

   b. Ph Content

      The pH test was conducted to determine the acidity or alkalinity level of a solution using a pH meter. A higher pH value indicates a more alkaline solution, while a lower pH value indicates a more acidic solution. The pH scale ranges from 0 to 14, with neutral pH at 7. Based on the test results, the acidity level of Batanghari River water was recorded at 6,54.

5.2.2 The Effect of Asphalt Content on the Mixture for Determining OAC

The determination of the OAC in the AC-BC mixture was carried out by considering parameters such as stability, flow, Marshall Quotient, VITM, VMA, VFWA, and density. The analysis of the Marshall test results served as the basis for establishing the OAC value, as described in the following discussion.

1. Analysis of the Effect of Stability Value on Determining OAC

   Stability refers to the ability of pavement to withstand traffic loads without experiencing permanent deformation, such as rutting, corrugation, or asphalt bleeding. This parameter is crucial to prevent premature damage that could endanger safety. By optimizing asphalt content, the mixture can be designed

to be both strong and flexible, thus capable of sustaining traffic loads continuously. The stability values of the AC-BC mixture are presented in Figure 5.3.

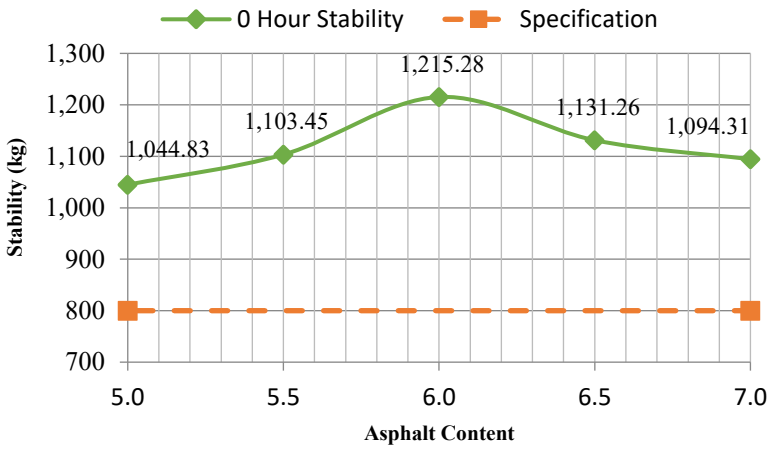


Figure 5.3 Graph of Effect of Asphalt Content on Stability Value

As shown in Figure 5.3, the stability of the AC-BC mixture increases with asphalt content, reaching a peak value of 1215,28 kg at 6% asphalt content, before declining. This increase occurs due to improved internal cohesion resulting from a uniform asphalt film coating the aggregate surfaces. However, at asphalt contents above the optimum point, an excessively thick asphalt film produces a lubrication effect, reducing inter-particle bonding and thereby decreasing stability. Nevertheless, the stability values within the asphalt content range of 5% to 7% still meet the minimum requirement of 800 kg, as stipulated in the 2018 Bina Marga General Specifications Revision 2.

2. Analysis of the Effect of Flow Value on Determining OAC

The flow parameter in the Marshall test measures the deformation of the asphalt mixture at maximum load, which indicates the flexibility level of the mixture. This parameter ensures that the pavement can withstand traffic loads and environmental effects without experiencing excessive deformation. The flow values for the AC-BC mixture are presented in Figure 5.4.

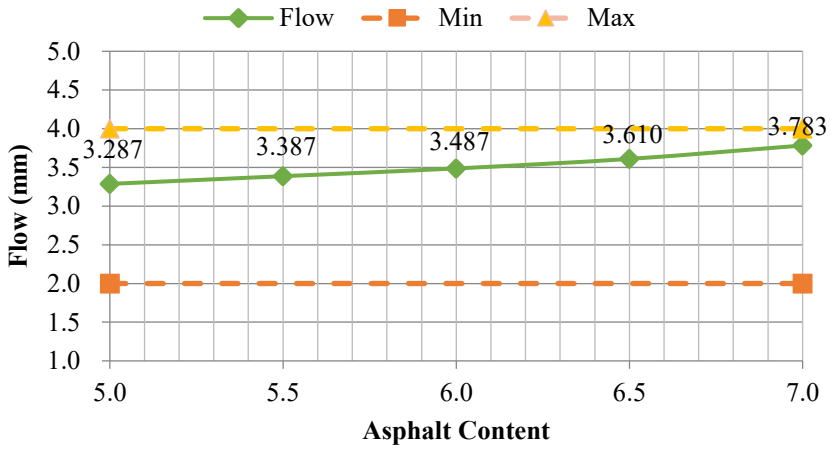


Figure 5.4 Graph of Effect of Asphalt Content on Flow Value

Based on Figure 5.4, the flow value increases with higher asphalt content due to the thickening of the asphalt film coating the aggregates, thereby enhancing the plasticity of the mixture. A more plastic mixture tends to deform more easily under traffic loads. According to the 2018 Bina Marga General Specifications Revision 2, the flow value for AC-BC mixtures must fall within the range of 2–4 mm. The flow values at asphalt contents of 5%–7% still meet the specified limits.

3. Analysis of the Effect of MQ Value on Determining OAC

MQ is the ratio between stability and flow from the Marshall test, used to determine the optimum asphalt content and to evaluate the performance of the mixture under load. The MQ values can be seen in Figure 5.5.

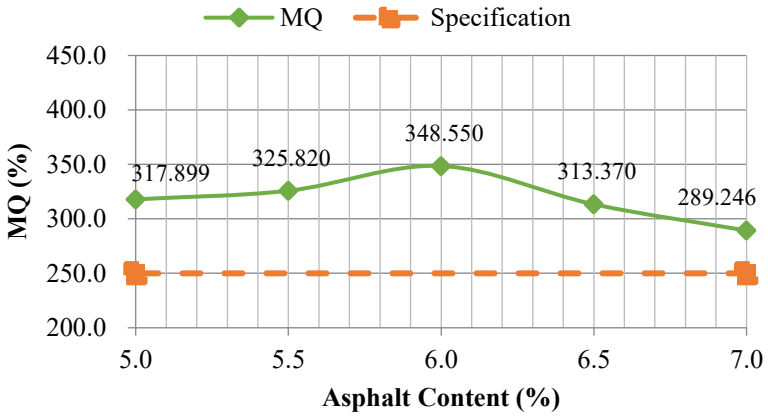


Figure 5.5 Graph of Effect of Asphalt Content on MQ Value

As shown in Figure 5.5, the MQ increases with asphalt content, reaching its peak at 6%, and then decreases at higher asphalt contents. This increase occurs because the binder fills the voids between aggregate particles, thereby enhancing the internal adhesion between asphalt and aggregate, resulting in a mixture with higher stiffness and lower plastic deformation. However, beyond the optimum asphalt content, the excess asphalt acts as a lubricant between aggregate particles, reducing internal bond strength and increasing mixture plasticity, which leads to a decrease in MQ values. Nevertheless, all MQ values within the asphalt content range of 5% to 7% still meet the minimum requirement of 250 kg/mm, in accordance with the 2018 Bina Marga Specifications Revision 2.

4. Analysis of the Effect of VITM Value on Determining OAC

VITM is the percentage of air voids contained in the compacted asphalt mixture, defined as the ratio between the volume of air voids and the total volume of the mixture. These voids represent the empty spaces between the aggregates and asphalt that are not filled with asphalt.

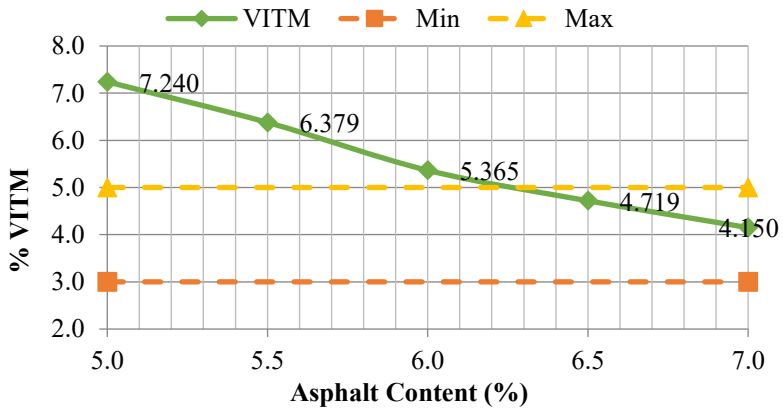


Figure 5.6 Graph of Effect of Asphalt Content on VITM Value

Figure 5.6 shows that the VITM value decreases with increasing asphalt content, as the air voids in the mixture are gradually filled with asphalt. However, at asphalt contents of 5%, 5.5%, and 6%, the resulting VITM values fall outside the range specified in the 2018 Bina Marga

Specifications Revision 2, which sets the minimum limit at 3% and the maximum at 5%.

5. Analysis of the Effect of VMA Value on Determining OAC

VMA in asphalt pavement is the percentage of air voids between the mineral aggregate particles in the compacted asphalt mixture, including the space filled with effective asphalt and air. The VMA values are shown in Figure 5.7.

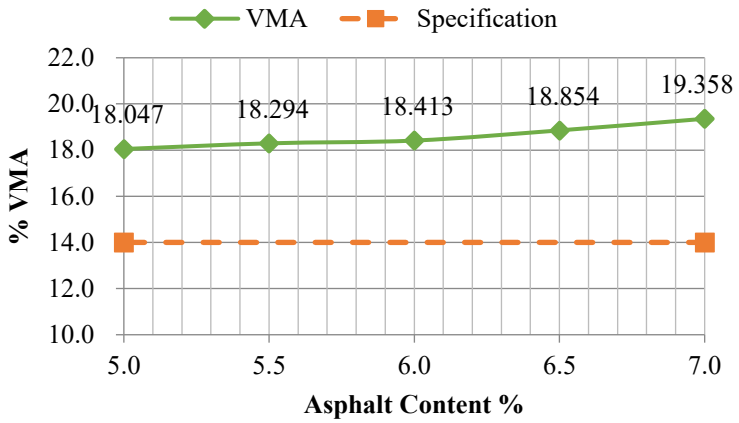


Figure 5.7 Graph of Effect of Asphalt Content on VMA Value

Figure 5.7 shows that the VMA value increases in line with the increase in asphalt content, starting from the minimum point at 5% asphalt content and reaching the maximum point at 7%. The increase in VMA is caused by the addition of asphalt content, which forms a thicker asphalt film on the surface of the aggregates, thereby widening the distance between particles. Nevertheless, all VMA values within the asphalt content range of 5% to 7% still meet the requirement, namely above the minimum limit of 15%, as specified in the 2018 Bina Marga Specifications Revision 2.

6. Analysis of the Effect of VFWA Value on Determining OAC

VFWA is the percentage of voids in the mixture that are filled with asphalt. In other words, VFWA indicates how much asphalt occupies the empty spaces between the aggregate particles in the mixture. VFWA values tend to increase with higher asphalt content, as shown in Figure 5.8.

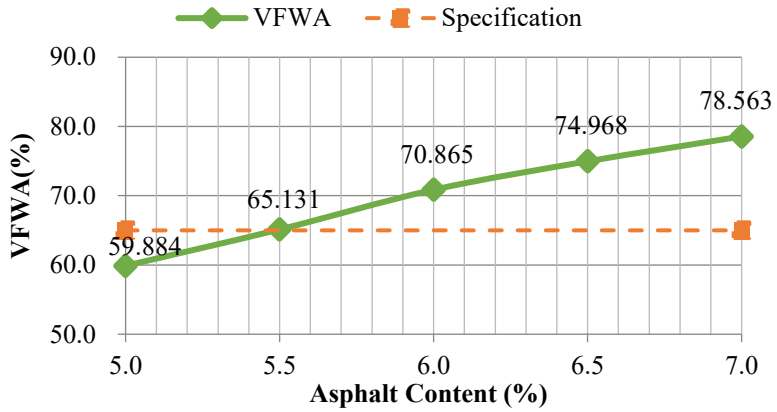


Figure 5.8 Graph of Effect of Asphalt Content on VFWA Value

Figure 5.8 shows that the VFWA value increases as asphalt content increases, starting from the lowest point at 5% and reaching its peak at 7%. This increase occurs because more asphalt fills the air voids within the mixture. Nevertheless, at asphalt contents of 5.0%, the VFWA values are still below the minimum limit of 65% specified in the 2018 Bina Marga Specifications Revision 2.

7. Analysis of the Effect of Density Value on Determining OAC

Density plays a role in measuring the degree of compaction and tightness of a material. Mixtures with higher density generally have better capability in supporting traffic loads. The density values for the AC-BC mixture are presented in Figure 5.9.

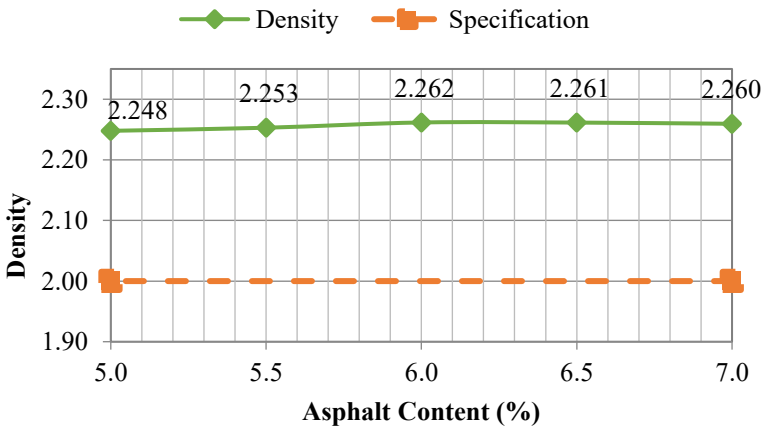


Figure 5.9 Graph of Effect of Asphalt Content on Density Value

Figure 5.9 shows that the density value increases as the asphalt content reaches 6%, then decreases at 6–7%. The increase in density is caused by the asphalt filling the voids between aggregates, making the mixture more compact. Conversely, the decrease in density at 6–7% asphalt content occurs due to excess asphalt acting as a lubricant, thereby reducing the inter-particle tightness of the aggregates. Nevertheless, all density values within the asphalt content range of 5–7% remain above the minimum limit of 2 g/cm³, as stipulated in the 2018 Bina Marga Specifications Revision 2.

5.2.3 Marshall Characteristics at OAC of Mixture with Glass Powder (GP) Filler Substitution

Based on the Marshall test, the OAC for the AC-BC mixture using Pertamina Pen 60/70 asphalt was determined to be 6.59%**.** The mixture was then tested after immersion in river water for 24 and 48 hours, with the non-immersed mixture serving as the control. The test results indicated changes in performance characteristics due to immersion, which are discussed in the following section.

1. Analysis of the Effect of River Water Immersion on the Stability Value of Mixtures with Glass Powder Substitution

   The results of the stability test of AC-BC mixtures with glass powder filler substitution under various immersion durations in river water are shown in Figure 5.10**.**

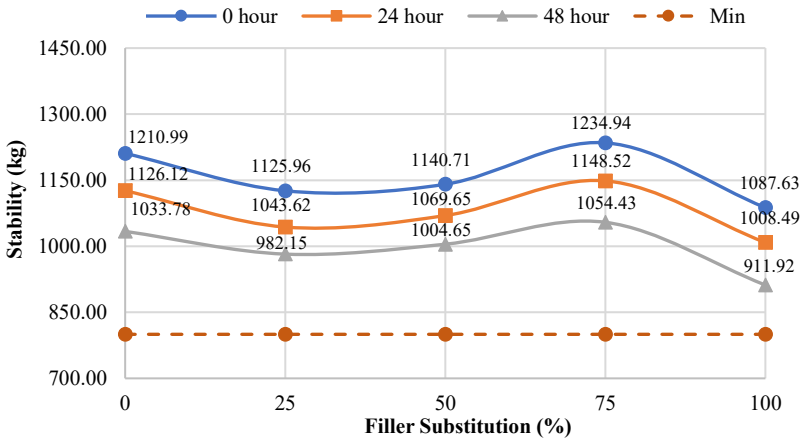


Figure 5.10 Graph of the Relationship between GP Filler Content and Stability Value under Different Immersion Duration

Based on Figure 5.10, the addition of glass powder filler in the mixture with 0-hour immersion resulted in a 7,02% decrease in stability at the 25% substitution level, a 1,31% increase at 50%, a further 8,25% increase at 75%, followed by a sharp 11,95% decrease at 100% filler substitution. In general, stone dust as a filler tends to provide higher and more consistent stability compared to glass powder, particularly for pavements subjected to heavy traffic loads. This is attributed to its mechanical properties, good density, and higher specific gravity. Nevertheless, glass powder can still serve as a feasible alternative, especially when applied in proper proportions and under controlled environmental conditions, while also offering the additional advantage of being an environmentally friendly material. This finding is consistent with the study by Yuniarti R, et al. (2019), which reported that the use of glass waste filler at 50% and 75% substitution levels produced higher stability values. At these compositions, glass powder and stone dust react with asphalt to form a paste that strengthens the mixture. The chemical reaction between the silica and alumina content in glass waste with stone dust and molten asphalt during the hot mixing process produces strong bonds, with maximum strength achieved at 75% glass waste filler substitution**.** Although increasing the proportion of glass powder can enhance stability by filling voids and strengthening the bond between filler and binder through its angular particle shape, the decrease in stability at the 25% level occurs due to the less-than-optimal interaction between the two types of filler. The significant drop at 100% substitution is attributed to the smooth surface of glass powder, which reduces adhesion to asphalt, thereby increasing voids and lowering mixture density.

Figure 5.10 also illustrates that the longer the immersion duration, the lower the resulting stability. At 24 hours of immersion, the stability of the mixture with 0% glass powder filler decreased by 7,01**%**, and further decreased by 8,20**%** at 48 hours of immersion. The reduction in stability was caused by river water penetrating the aggregate layer, which weakened the bond between asphalt and aggregate. These findings are in line with Arifin and

Tugiman (2022), who reported that the decline in stability value was due to water penetration into the aggregate layer, thereby reducing the durability of the asphalt layer.

2. Analysis of the Effect of River Water Immersion on the Flow Value of Mixtures with Glass Powder Substitution

The Flow test results of AC-BC mixtures with glass powder filler substitution under various immersion durations in river water are shown in Figure 5.11.

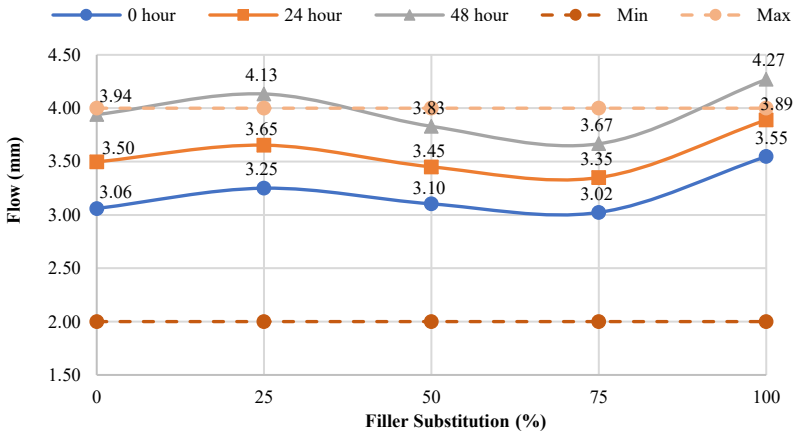


Figure 5.11 Graph of the Relationship between GP Filler Content and Flow Value under Different Immersion Durations

As seen in Figure 5.11, the Flow value at 0-hour immersion increased by 6,21**%** at the 25% filler level, decreased by 4,62**%** at 50%, and further decreased by 2,58**%** at 75%, followed by a sharp 17,55% increase at 100% filler substitution. In general, Flow is defined as the ability of asphalt concrete layers to withstand repeated loading without experiencing damage such as cracking and rutting. A higher Flow value indicates that the asphalt mixture is less stiff and more prone to deformation. Conversely, a lower Flow value suggests a stiffer asphalt mixture that can better withstand traffic loads.

The Flow value of the asphalt mixture with 25% glass powder filler was higher compared to the mixture using 100% stone dust filler. This increase

occurred because the 25% composition of glass powder filler was not optimal, making the asphalt concrete mixture less capable of resisting deformation. These results are consistent with the findings of Ridha, et al. (2020), who reported that increasing the percentage of glass waste (10%–40%) made the specimens less plastic. This is due to the poor interaction between glass waste and asphalt.

The decrease in Flow value at 50–75% filler substitution was caused by the greater filling of voids in the mixture by glass powder, more optimal blending of the filler, and the contribution of angular particles that improved structural stiffness. However, at 100% glass powder filler, the smooth surface of the glass particles reduced adhesion with asphalt, increased void content, and made the mixture more plastic and susceptible to deformation.

Figure 5.11 also indicates that the longer the immersion duration, the higher the Flow value. At 0% glass powder substitution, Flow increased by 14.38**%** after 24 hours of immersion compared to 0 hours. This increase reflects the weakening of the mixture structure due to water exposure, making it more prone to deformation under loading. These findings are in line with Arifin and Tugiman (2022), who stated that the longer the immersion duration, the higher the Flow value, showing that the mixture becomes more easily deformed and more plastic. According to Bina Marga 2018 Revision 2 Specifications**,** the Flow value for AC-BC mixtures should fall within the range of 2–4 mm. However, at 25% and 100% filler substitution**,** the Flow values after 48 hours of immersion did not meet this requirement

3. Analysis of the Effect of River Water Immersion on Mixtures with Glass Powder Substitution on MQ Values

   The MQ test results of AC-BC mixtures with glass powder filler substitution under varying immersion durations in river water are presented in Figure 5.12 below.

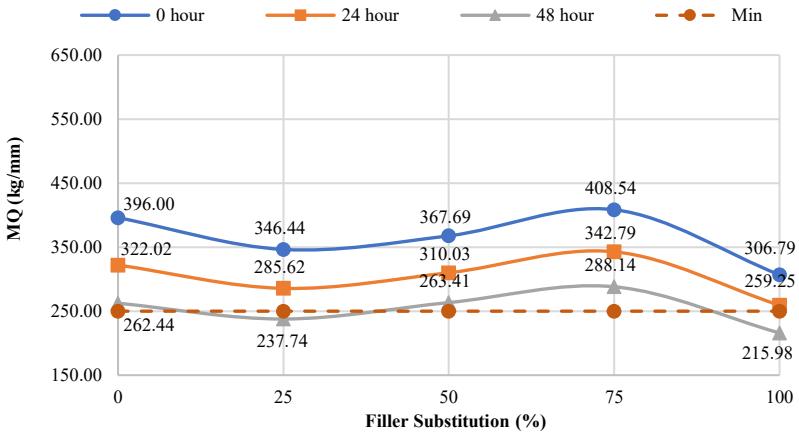


Figure 5.12 Graph of the Relationship between GP Filler Content and MQ Value under Different Immersion Durations

Figure 5.12 shows that at 0 hours of immersion, the initial MQ value decreased by 12,53% at 25% glass powder filler substitution, then increased by 6,13% at 50% substitution, reaching its peak at 75% substitution with an increase of 11,11%, before experiencing a sharp decline of 24,91% at 100% substitution. The increase in MQ values indicates that the mixture possesses greater stiffness and resistance to deformation. The maximum value observed at 75% substitution was achieved due to the high stability of the mixture, supported by optimal void filling by the filler and low flow values, resulting in a stiff and stable structure. This finding is consistent with the study by Hasan, et al. (2025), which reported that the addition of glass powder enhances mixture stiffness by reducing voids; however, excessive amounts may reduce the mixture's flexibility under loading.

Furthermore, Figure 5.12 illustrates that MQ values decrease with longer immersion durations, indicating reduced stiffness of the mixture due to river water exposure. At 0% glass powder substitution, MQ decreased by 18.68% after 24 hours of immersion compared to 0 hours, and further decreased by 18.48% after 48 hours. This result aligns with the study by Mawarni and Fauziah (2019), which reported that porous asphalt mixtures using Pen 60/70 binder and crumb rubber asphalt experienced reductions in stability,

flow, and MQ with increasing immersion durations in seawater. According to the 2018 Bina Marga Specifications (Revision 2), the minimum required MQ value for AC-BC mixtures is 250 kg/mm. Therefore, mixtures with 25% substitution did not meet the minimum requirement after 48 hours of immersion.

4. Analysis of the Effect of Glass Powder Filler Content on VITM Values

The VITM test results of AC-BC mixtures with glass powder filler substitution are presented in Figure 5.13.

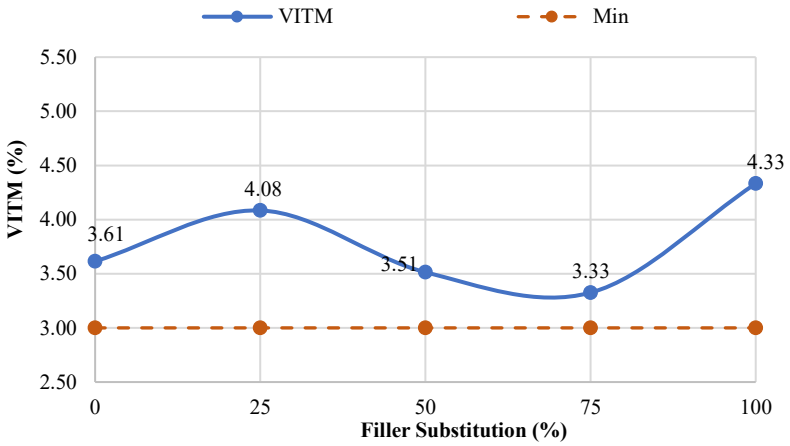


Figure 5.13 Graph of the Relationship between GP Filler Content and VITM Value

Based on Figure 5.13, the VITM value at 0 hours of immersion increased by 13.01% at 25% glass powder substitution, then decreased by 13,97% at 50% substitution, followed by a further decline of 5,13% at 75%, and subsequently increased significantly by 30,03% at 100%. The initial increase at 25% occurred due to an imbalance in the proportion of stone dust and glass powder, which resulted in a less dense mixture. The reduction in VITM up to 75% substitution was attributed to the ability of glass powder to fill voids more effectively, thereby enhancing mixture density. However, at 100% substitution, the VITM value rise again because the smooth surface of glass powder reduced adhesion with asphalt, hindering the formation of a dense structure. Elevated VITM values increase the risk of water infiltration,

which may accelerate bond deterioration and shorten pavement service life. Consistent with the findings of Kifile, et al. (2024), higher glass powder content tends to reduce VITM due to more efficient particle compaction and packing. Nevertheless, at excessive levels, glass powder alone becomes less effective in forming strong bonds with asphalt, resulting in a subsequent increase in VITM.

5. Analysis of the Effect of Glass Powder Filler Content on VMA Values

The VMA test results of AC-BC mixtures with glass powder filler substitution are presented in Figure 5.14.

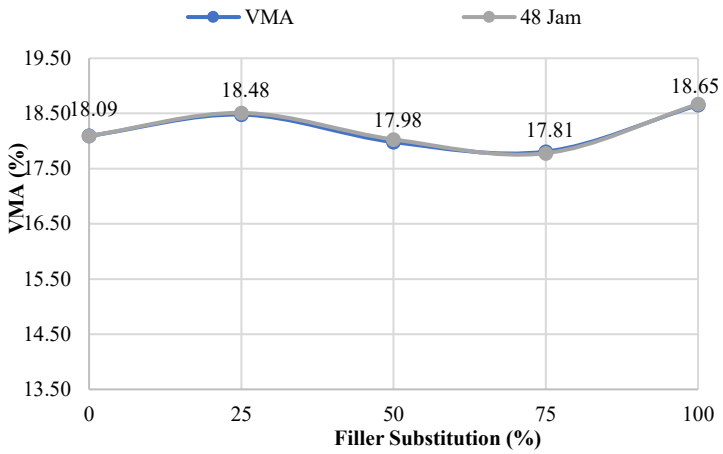


Figure 5.14 Graph of the Relationship between GP Filler Content and VMA Value

Based on Figure 5.14, the VMA graph analysis demonstrates the influence of glass powder substitution on the volumetric properties of the asphalt mixture. An increase in VMA of 2,16% was observed from 0% to 25% substitution. This occurred due to initial disruption in aggregate compaction, caused by the lower specific gravity of glass powder and its particle characteristics, which differ from stone dust filler. Subsequently, VMA decreased by 2,71% at 50% substitution and declined further by 0,94% at 75% substitution, reflecting improved compaction and optimal interaction between filler and binder, which aligns with the increase in density and maximum stability of the mixture. However, at 100% substitution, VMA

rise again by 4,71%, indicating that excessive glass powder reduces mixture workability, thereby increasing voids and potentially decreasing performance. This result is consistent with the findings of Choudhary, et al. (2021), who reported that VMA decreases with increasing glass powder content up to 8,5%, primarily due to the filler's ability to occupy more voids between aggregates. The observed VMA behavior also reflects changes in the air void content within the mixture.

6. Analysis of the Effect of Glass Powder Filler Content on VFWA Values

The VFWA test results of AC-BC mixtures with glass powder filler substitution are presented in Figure 5.15.

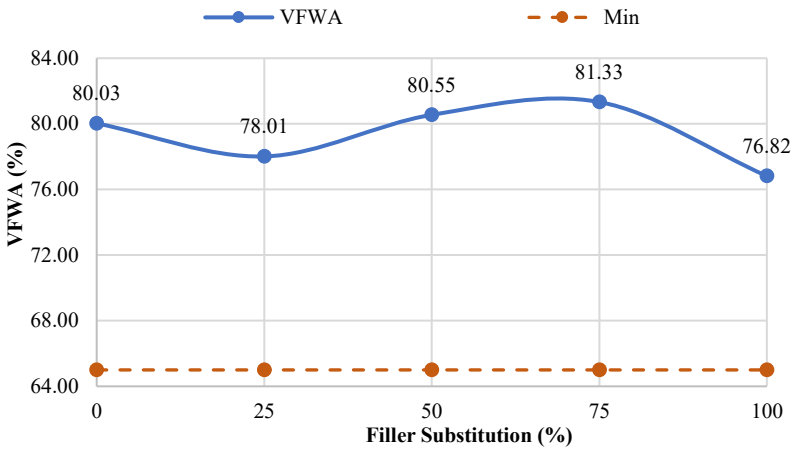


Figure 5.15 Graph of the Relationship between GP Filler Content and VFWA Value

Based on Figure 5.15, the VFWA graph analysis illustrates the effect of glass powder substitution on the properties of asphalt mixtures. At 25% substitution, VFWA decreased by 2,53%, indicating initial disruption in aggregate compaction. It then increased by 3,25% at 50% substitution and continued to rise by 0,97% at 75%, reflecting a more uniform distribution of asphalt. However, at 100% substitution, VFWA dropped again by 5.55% due to excessive glass powder content. These findings are consistent with the study of Kifile, et al. (2024), which reported that VFWA values increased with glass waste content up to 7%, but declined at 10% due to the growth of

air voids, thereby reducing the proportion of voids available to be filled with asphalt.

7. Analysis of the Effect of Glass Powder Filler Content on Density Values

The density test results of AC-BC mixtures with glass powder filler substitution are presented in Figure 5.16.

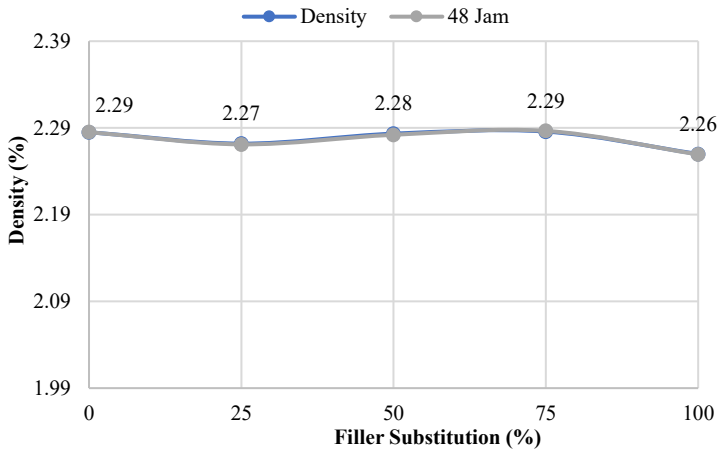


Figure 5.16 Graph of the Relationship between GP Filler Content and Density Value

Based on Figure 5.16, mixtures with glass powder filler substitution exhibited a slightly higher density at 75% substitution compared to mixtures using stone dust filler. The increase in density occurred due to the interaction between glass powder and stone dust, which formed a paste when heated, resulting in a denser mixture with tighter voids. This finding is in line with the study conducted by Ridha, et al. (2020), which reported that density values increased with higher glass waste content due to reduced voids within the mixture.

A density reduction was observed at 25% substitution, amounting to 0,87%, caused by the suboptimal interaction between the two types of filler. However, density increased again at 50% substitution by 0,44% and continued to rise by another 0,44% at 75% substitution, as the additional filler contributed to filling voids and enhancing mixture compactness. At

100% glass powder substitution, density values decreased by 1.31%, attributed to reduced asphalt binding capacity, which increased voids within the mixture and consequently lowered density.

5.2.4 IRS Test Characteristics at OAC of Mixtures GP Filler Substitution

The IRS test aims to measure the reduction in cohesion due to the effect of water on compacted asphalt mixtures, serving as an indicator of moisture resistance. IRS values are calculated by comparing the stability of unconditioned samples (0,5-hour immersion) with conditioned samples (24-hour immersion). Figures 5.17, 5.18, and 5.19 sequentially present the comparison of stability values between unconditioned and conditioned samples at immersion durations of 0 hours, 24 hours, and 48 hours.

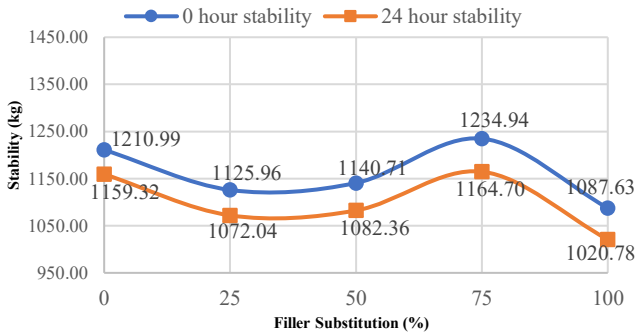


Figure 5.17 Graph of the Relationship between Soaking and Stability at 0-Hour Soaking Duration

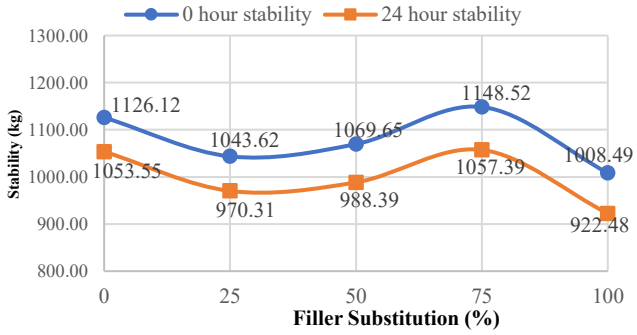


Figure 5.18 Graph of the Relationship between Soaking and Stability at 24-Hour Soaking Duration

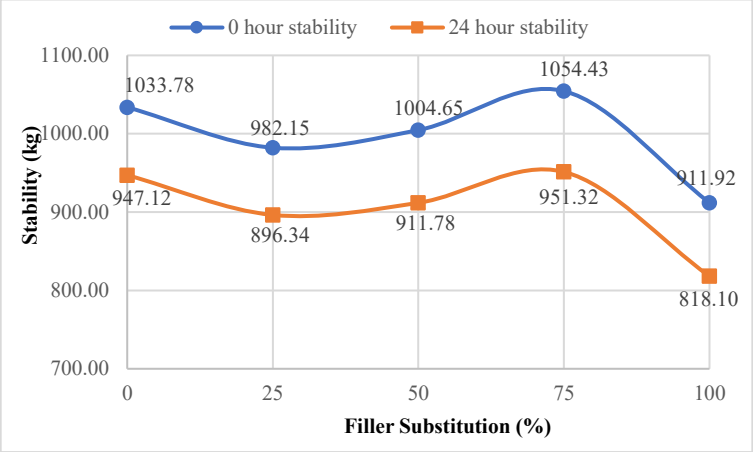


Figure 5.19 Graph of the Relationship between Soaking and Stability at 48-Hour Soaking Duration

Based on these figures, it can be concluded that, in general, the stability of conditioned samples is lower than that of unconditioned samples. This reduction occurs because water penetrating the pores of the mixture weakens the bond between asphalt and aggregate. The graph illustrating IRS values according to the variation in GP substitution is shown in Figure 5.20.

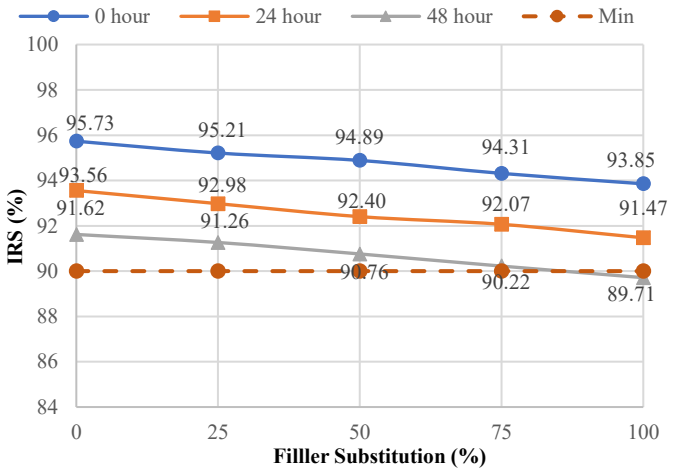


Figure 5.20 Graph of the Effect of GP as a Filler Substitute on IRS

From the test results presented in Figure 5.20, it can be observed that the use of glass powder filler has a negative impact on the performance of asphalt mixtures. As the substitution level of glass powder filler increases, IRS values

decrease. At 0-hour immersion, IRS decreased by 0,54% at 25% substitution, continued to decline by 0,34% at 50%, dropped further by 0,61% at 75%, and decreased by 0,49% at 100% substitution. The decline in IRS values with increasing glass powder filler is attributed to the physical and chemical properties of glass powder that affect asphalt–aggregate bonding. Glass powder has a smooth texture and high silica content, which may reduce adhesion between asphalt and aggregate. As the filler content increases, the pores in the asphalt mixture become more susceptible to water penetration, weakening cohesion and mixture stability, especially after prolonged immersion (24 hours and 48 hours). Furthermore, the non-porous and slippery nature of glass powder reduces bonding capacity, leading to significant decreases in stability.

The graph in Figure 5.20 also indicates that IRS values decrease with longer immersion durations in river water. This reduction occurs because extended immersion allows water to penetrate deeper into the pores of the mixture and aggregates, causing asphalt to strip from aggregate surfaces. This weakens the asphalt–aggregate bond and ultimately reduces the structural strength of the mixture. In addition, the slightly acidic nature of river water accelerates bond degradation, particularly when combined with suspended particles in turbid water that may become trapped in the mixture's voids, aggravating the condition. These findings are consistent with Fauziah and Handaka (2017), who reported that IRS values decline with increasing immersion duration, with sharper reductions observed in mixtures using conventional Pen 60/70 asphalt.

According to the 2018 Bina Marga Specifications (Revision 2), the minimum IRS value must exceed 90%. Therefore, IRS values at 24-hour immersion with 100% substitution, as well as those at 48-hour immersion, do not meet the specified standard.

5.2.5 ITS Test Characteristics at OAC of Mixtures with GP Filler Substitution

The ITS test is a method used to measure the indirect tensile strength of asphalt mixtures. The ITS value reflects the tensile strength of the asphalt mixture, indicating its ability to resist forces that may trigger cracking, either due to

repeated traffic loads or temperature variations. The higher the ITS value, the better the asphalt mixture's resistance to cracking risk. The ITS test results with GP filler substitution are shown in Figure 5.21.

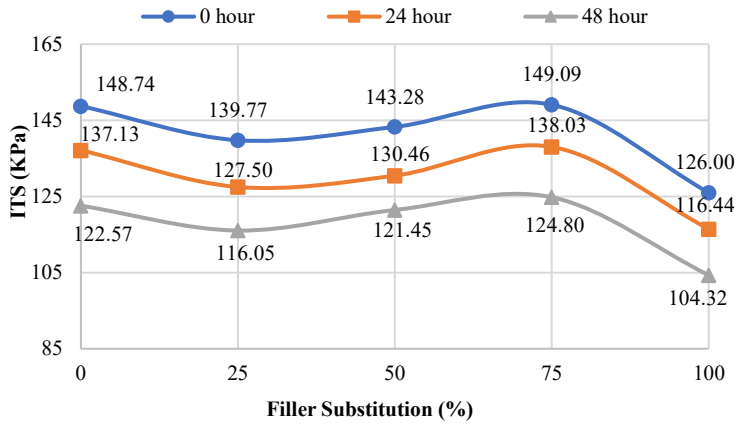


Figure 5.21 Graph of the Effect of GP as a Filler Substitute on ITS

As presented in Figure 5.21, the ITS value decreased by 6,03% at 25% glass powder filler substitution, increased by 2,51% at 50% substitution, and continued to rise by 4,05% until reaching the optimum point at 75% substitution, before experiencing a significant decrease of 15,49% at 100%. The reduction observed at 25% substitution occurred due to the suboptimal proportion of filler between stone dust and glass powder. The increase up to 75% substitution was attributed to the denser and more optimal combination of glass powder and stone dust, as the glass powder partially melted together with stone dust to form a strong paste capable of filling voids in the mixture. The significant decline at 100% substitution occurred because of the absence of stone dust as a binding component for the fine-textured glass powder, which weakened particle bonding. This finding is consistent with the study of Yuniarti, et al. (2019), which reported that the optimum ITS value was achieved at 75% substitution of glass powder filler.

Figure 5.21 also shows that longer immersion durations in river water lead to reductions in ITS values. At 0% substitution of glass powder filler, ITS decreased by 7,78% after 24 hours of immersion compared to 0 hours, and declined further by 10,64% after 48 hours of immersion. The weakening of adhesion between asphalt and aggregates resulted in reduced tensile strength of

the mixture. This result aligns with the findings of Tajudin and Suparma (2017), who reported that longer immersion durations led to decreasing ITS values due to the reduction in adhesion between asphalt and aggregate caused by water intrusion.

5.2.6 TSR Test Characteristics at OAC of Mixtures with GP Filler Substitution

TSR test is a method used to evaluate the resistance of asphalt mixtures to moisture-induced damage. This test compares the indirect tensile strength of asphalt mixture specimens conditioned in water with those in dry conditions. The TSR value is calculated as the ratio between the indirect tensile strength of specimens immersed in a water bath for 24 hours and that of unconditioned specimens. The graph showing the effect of glass powder filler substitution on TSR values is presented in Figure 5.22.

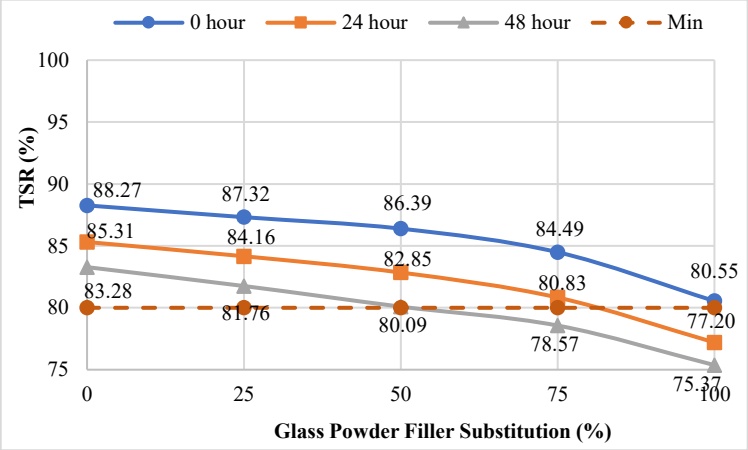


Figure 5.22 Graph of the Effect of GP as a Filler Substitute on TSR

As shown in Figure 5.22, at 0-hour immersion, TSR decreased by 1,08% at 25% substitution, further declined by 2,13% at 50%, dropped by 4,28% at 75%, and fell significantly by 8,74% at 100% substitution. The TSR value of mixtures without glass powder filler was higher than those with substitution. It can therefore be concluded that the substitution of glass powder filler reduced the mixture's resistance to water penetration. At 100% substitution, TSR values declined sharply due to the smooth surface characteristics of glass powder, which

weakened bonding between asphalt particles. These findings are consistent with the study by Choudhary, et al. (2021), which reported that glass powder filler demonstrated poor performance in terms of moisture resistance.

Increasing river water immersion duration also affected the overall decline in TSR values across all substitution variations. Prolonged immersion reduced the tensile durability of mixtures, as evidenced by a 3,35% reduction at 0% substitution after 24 hours of immersion compared to 0 hours, followed by a further 2,38% decline after 48 hours. These results align with the findings of Tajudin and Suparma (2017), who stated that TSR values decrease with increasing immersion duration. This occurs because water weakens the bond between aggregate and asphalt, leading to reductions in tensile strength.

According to the 2018 Bina Marga Specifications (Revision 2), the minimum TSR value must exceed 80%. Therefore, TSR values at 48-hour immersion with 75% and 100% substitution did not meet the specified standard.

5.2.7 CL Test Characteristics at OAC of Mixtures with GP Filler Substitution

The CL test is conducted to evaluate the abrasion resistance of asphalt mixtures by rotating test specimens in a Los Angeles machine. This test serves as an indicator of the mixture's durability against traffic-induced abrasion. The CL test results showing the effect of glass powder filler substitution on abrasion resistance are presented in Figure 5.23.

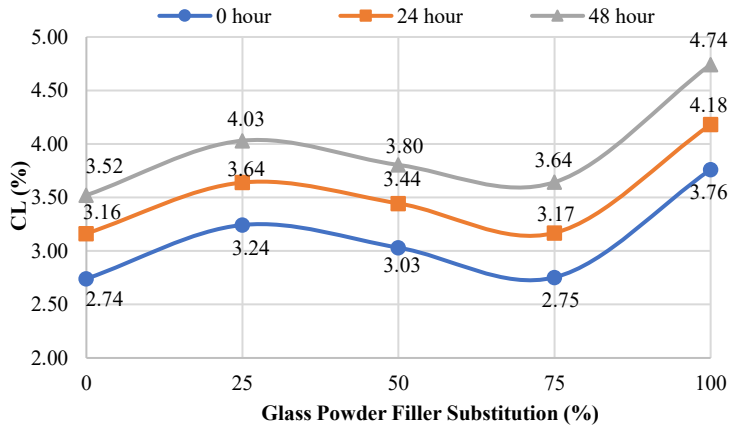


Figure 5.23 Graph of the Effect of GP as a Filler Substitute on CL

An increase in CL values indicates that the mixture has lower resistance to abrasion, whereas a decrease suggests that the mixture is stronger in withstanding abrasion. As shown in Figure 5.23, the CL value increased by 18,25% at 25% substitution, then decreased by 6,48% at 50%, and further decreased by 9,24% at 75%, before rising significantly by 36,73% at 100% substitution. The increase at 25% substitution occurred due to the suboptimal proportion between stone dust and glass powder filler, which disrupted the stability compared to mixtures with 0% substitution. The decreases observed at 50% and 75% substitutions indicate that at these proportions, the mixture became denser and stronger in resisting abrasion, as voids were effectively filled by the combination of stone dust and glass powder filler. The significant increase at 100% substitution was attributed to weak bonding between asphalt and aggregates, as the smooth surface of glass powder filler was ineffective in binding the mixture in the absence of stone dust, resulting in poor abrasion resistance.

CL values also tended to increase with longer immersion durations. This occurred because prolonged immersion weakened the adhesion between asphalt and aggregate due to water penetration into the pores of the mixture. This process softened the asphalt and facilitated the detachment of aggregate particles. Consequently, the longer the immersion duration, the higher the potential for mass loss in the mixture, as reflected in the increased CL values. These findings are consistent with the study of Harahap, et al. (2019), which showed that CL graphs under peat water immersion from day 0 to day 7 exhibited increases at every rotation count, indicating that asphalt concrete experienced mass reduction and strength loss.

CHAPTER VI
CONCLUSIONS AND SUGGESTIONS

6.1 Conclusions

Based on the results and analysis of the characteristics of AC-BC mixtures with glass powder filler substitution and variations in river water immersion duration, the following conclusions can be drawn:

1. The use of glass powder filler as a substitute material affects the Structural Strength characteristics of the AC-BC mixture, indicated by an fluctuated in stability, MQ, Flow and ITS values. However, at full substitution (100%), all performance parameters experienced a significant decline. In addition, the longer the immersion duration in river water, the stability and MQ values tended to decrease, while the flow value increased, indicating that the load-bearing capacity of the mixture diminishes with prolonged immersion.
2. AC-BC mixtures using glass powder filler substitution affect the durability characteristic, showed a tendency of fluctuated CL values as the substitution level increase, IRS and TSR decrease. Increase of immersion duration in river water produce higher value of CL and decrease in IRS and TSR value. Therefore, it can be concluded that such mixtures have low resistance to moisture, making them more susceptible to stripping
3. The use of glass powder as a filler substitute in AC-BC mixtures affects the volumetric characteristic, where an fluctuated value was observed up to a certain substitution level. However, at 100% substitution, VITM and VMA value increase sharply. Meanwhile, VFWA and density with 100% filler substitution drop sharply. This indicates that excessive filler use can escalate the mixture’s void.

6.2 Suggestions

Referring to the findings of this study on the use of glass powder filler substitution in AC-BC mixtures under Batanghari River water immersion, the author offers several recommendations for future research, as follows.

1. Further research may be conducted by examining the chemical composition and compound characteristics of glass powder filler and river water in order to obtain a more detailed understanding of their effects on AC-BC mixtures.
2. The findings of this study may differ from previous or future research, as the composition and properties of the glass powder used can vary. Therefore, the author strongly recommends conducting a thorough analysis of the glass powder content prior to its utilization.
3. Subsequent studies are suggested to employ environmentally friendly and hydrophobic fillers to develop pavements that are more resistant to moisture and water exposure

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APPENDIX

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 1 Specific Gravity Test of Asphalt Pen 60/70

SPECIFIC GRAVITY OF ASPHALT

REFERENCE : SNI 2441 - 2011

1 Material Source : Pertamina
2 Material Type : Pertamina Asphalt Pen 60/70
3 Test Conducted in : 2025

No.	Test Description	Sample	
		1	2
1	Weight of empty pycnometer (gr)	23,89	23,45
2	Weight of pycnometer + distilled water (gr)	46,32	46,56
3	Weight of distilled water (2 - 1) (gr)	22,43	23,11
4	Weight of pycnometer + asphalt (gr)	25,85	25,4
5	Weight of asphalt (4 - 1) (gr)	1,96	1,95
6	Weight of pycnometer + asphalt + distilled water (gr)	46,42	46,61
7	Weight of distilled water (6 - 4) (gr)	20,57	21,21
8	Volume of asphalt (3 - 7) (gr)	1,86	1,9
9	Specific gravity of asphalt = Weight / Volume (5/8)	1,05	1,026
10	Average specific gravity of asphalt	1,040	

Yogyakarta, August 2025

Approved by
Laboratory Manager of Civil Engineering

Ir. Bernah Kushari, M.Eng, IPM, ASEAN.Eng
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 2 Asphalt Penetration Test Pen 60/70

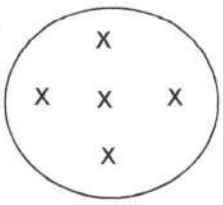
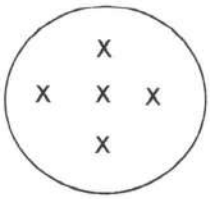
ASPHALT PENETRATION TEST

REFERENCE; AASHTO T 49-68, ASTM D 5-71

1 Material Source : Pertamina
2 Material Type : Pertamina Asphalt Pen 60/70
3 Test Conducted in : 2025

No	Test Sequence	Temperature Meas.	Time Meas.	Remarks
1	**Heating of speciment**			
	Start of heating	27 ^{o}C	10.00 WIB	
	End of heating	140 ^{o}C	10.30 WIB	
2	**Left at room temperature**			
	Start	140 ^{o}C	10.30 WIB	
	End	27 ^{o}C	13.00 WIB	
3	**Testing**			
	Start	25 ^{o}C	13.00 WIB	
	End	25 ^{o}C	13.30 WIB	

OBSERVATION RESULTS

No	Specimen		Test Sketch		Remarks
	I (mm)	II (mm)	Sample 1	Sample 2	
1	65	71			
2	65	72			
3	60	70			
4	61	73			
5	60	68			
Avg.	62,2	70,8			
Avg.	66,5				

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, M.Eng, IPM., ASEAN.Eng.
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 3 Flash Point and Fire Point Test of Asphalt Pen 60/70

FLASH POINT AND FIRE POINT TEST

REFERENCE; AASHTO T 48-74, ASTM D 92-52

1 Material Source : Pertamina
2 Material Type : Pertamina Asphalt Pen 60/70
3 Test Conducted in : 2025

No	Test Sequence	Temperature Meas.	Time Meas.	Remarks
1	**Heating of speciment**			
	Start of heating	27 ^{O}C	08.20 WIB	
	End of heating	140 ^{O}C	08.35 WIB	
2	**Left at room temperature**			
	Start	140 ^{O}C	08.35 WIB	
	End	27 ^{O}C	09.40 WIB	
3	**Testing**			
	Start	27 ^{O}C	09.40 WIB	
	End	310 ^{O}C	10.20 WIB	

OBSERVATION RESULTS

No	Description	Flash Point	Fire Point	Remarks
1	Sample 1	308 ^{O}C	313 ^{O}C	
2	Sample 2			
3	Average	308 ^{O}C	313 ^{O}C	

Yogyakarta, August 2025

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, M.Eng, IPM., ASEAN.Eng.
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 4 Softening Point Test of Asphalt Pen 60/70

SOFTENING POINT TEST ASPHALT

REFERENCE : SNI 2434 - 2011

1 Material Source : Pertamina
2 Material Type : Pertamina Asphalt Pen 60/70
3 Test Conducted in : 2025

No	Test Sequence	Temperature Meas.	Time Meas.	Remarks
1	**Heating of speciment**			
	Start of heating	27 ^{o}C	08.20 WIB	
	End of heating	140 ^{o}C	08.35 WIB	
2	**Left at room temperature**			
	Start	140 ^{o}C	08.35 WIB	
	End	27 ^{o}C	09.40 WIB	
3	**Testing**			
	Start	5 ^{o}C	13.15 WIB	
	End	48 ^{o}C	13.30 WIB	

OBSERVATION RESULTS

No.	Observed Temperature	Heating Time (Seconds)		Softening Point (^{o}C)	
		Sample I	Sample II	I	II
1	5 ^{o}C	0 second	0 second		
2	10 ^{o}C	137 second	137 second		
3	15 ^{o}C	112 second	112 second		
4	20 ^{o}C	101 second	101 second		
5	25 ^{o}C	107 second	107 second		
6	30 ^{o}C	115 second	115 second		
7	35 ^{o}C	124 second	124 second		
8	40 ^{o}C	128 second	128 second		
9	45 ^{o}C	135 second	137 second	48^{o}C	49^{o}C
10	50 ^{o}C				
11	55 ^{o}C				
12	60 ^{o}C				

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, M.Eng., IPM., ASEAN.Eng
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 5 Ductility Test of Asphalt Pen 60/70

DUCTILITY TEST (RESIDUE)

REFERENCE : AASHTO : T - 51 -74 ; ASTM D - 113 - 69

1 Sample Source : Pertamina
2 Sample Type : Pertamina Asphalt Pen 60/70
3 Date of Test : 2025

Test Preparation

No	Test Step	Description	Duration	Temperature
1	Specimen preparation	Asphalt heated	15 minutes	heating temp. ±135°C
2	Specimen cooling	Left at room temperature	60 minutes	room temp. ±28°C
3	Specimen soaking	Soaked in water at 25°C	60 minutes	water bath temp. ±25°C
4	Testing	Ductility tested at 25°C, speed 5 cm/min	20 minutes	equipment temp. ±25°C

Test Results

No	Specimen	Test Result	Remarks
1	Sample 1	137 cm	Not Broken
2	Sample 2	132 cm	Not Broken
4	Rata-rata	134,5 cm	

Yogyakarta, August 2025

Approved by
Laboratory Manager of Civil Engineering De

Ir. Berlian Kushari, M.Eng, IPM., ASEAN.Eng
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 6 Solubility Asphalt in *TCE*

SOLUBILITY TEST OF ASPHALT IN CCl_4 / TCE

REFERENCE : AASHTO T - 44 - 70 ; ASTM D - 165 - 42

1 Material Source : Pertamina
2 Material Type : Pertamina Asphalt Pen 60/70
3 Test Conducted : 2025

Test Preparation

No	Test Step	Description	Reading	
			Time	Temperature
1	Preparation	Start	14.00 WIB	28 °C
		End	14.10 WIB	28 °C
2	Weighing	Start	14.10 WIB	28 °C
3	Dissolving	Start	14.15 WIB	28 °C
4	Filtering	Start	14.20 WIB	28 °C
		End	14.25 WIB	28 °C
5	Oven Drying	Start	14.30 WIB	130 °C
6	Final Weighing	Start	14.30 WIB	28 °C

Test Results

No	Description	Specimen				Remarks
		1		2		
1	Weight of empty Erlenmeyer flask	54,400	gr	65,970	gr	
2	Weight of flask + asphalt	56,420	gr	68,010	gr	
3	Weight of asphalt (2 - 1)	2,020	gr	2,040	gr	
4	Weight of clean filter paper	0,580	gr	0,590	gr	
5	Weight of filter paper + mineral	0,590	gr	0,600	gr	
6	Weight of mineral (5 - 4)	0,010	gr	0,010	gr	
7	Mineral content (6/3x100%)	0,495	%	0,490	%	
8	Soluble asphalt (100% - 7)	99,505	%	99,510	%	
9	Average soluble asphalt(%)	99,507			%	

Yogyakarta, August 2025

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, M.Eng, IPM, ASEAN.Eng.
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 7 Specific Gravity Test of Coarse Aggregate

SPECIFIC GRAVITY TEST OF COARSE AGGREGATE

REFERENCE : SNI 03-1969-2008

1 Material Source : Clereng, Kulonprogo
2 Material Type : Coarse Aggregate
3 Test Conducted in : 2025

No.	Description	Specimen		Average
		1	2	
1	Weight of SSD specimen (BJ) gr	1611,62	1612,23	1611,93
2	Weight in water (BA) gr	1000,41	1000,80	1000,61
3	Oven-dry weight (BK) gr	1574,21	1568,25	1571,23
4	Spec. Gravity (Bulk) = $\frac{BK}{(BJ - BA}$	2,576	2,565	2,570
5	Spec. Gravity (SSD) = $\frac{BJ}{(BJ - BA}$	2,637	2,637	2,637
6	Spec. Gravity (Apparent) = $\frac{BK}{(BK - BA)}$	2,743	2,764	2,754
7	Water Absoprtion = $\frac{(BJ - BK)}{BK} \times 100\%$	2,376	2,804	2,590
8	Effective Specific Gravity = (G bulk + G apparent)/2	2,660	2,664	2,662

Yogyakarta, August 2025

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, M.Eng, IPM., ASEAN.Eng.
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 8 Aggregate Adhesion to Asphalt Test

AGGREGATE ADHESION TO ASPHALT TEST

1 Material Source : Clereng, Kulonprogo
2 Material Type : Coarse Aggregate
3 Test Conducted in : 2025

Test Preparation

No	Test Step	Temperature	Time	Remarks
1	**Heating the specimen**			
	Start	25°C	08.00 WIB	
	End	150°C	08.15 WIB	
2	**Cooling at room temperature**			
	Start	150°C	08.15 WIB	
	End	25°C	09.45 WIB	
3	**Soaking the specimen**			
	Start	25°C	09.45 WIB	
	End	25°C	10.15 WIB	

Test Results

No	Specimen	Test Result	Remarks
1	Sample 1	98%	
2	Sample 2	96%	
	Average	97%	

Yogyakarta, August 2025

Approved by
Laboratory Manager of Civil Engineering De

Ir. Berlian Kushari, M.Eng, IPM, ASEAN.Eng
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 9 Coarse Aggregate Abrasion Test Using the Los Angeles Machine

ABRASION TEST OF COARSE AGGREGATE

AASHTO T 96 - 77 ; SNI 2417 : 2008

1 Material Source : Clereng, Kulonprogo
2 Material Type : Coarse Aggregate
3 Test Conducted in : 2025

No	Gradation Type		B		Remarks
	Sieve		Specimen (gram)		
	Passing	Retained	1	2	
1	72.2 mm (3")	63.5 mm (2.5")			
2	63.5 mm (2.5")	50.8 mm (2")			
3	50.8 mm (2")	37.5 mm (1.5")			
4	37.5 mm (1.5")	25.4 mm (1")			
5	25.4 mm (1")	19.0 mm (3/4")			
6	19.0 mm (3/4")	12.5 mm (0.5")	2502,50		
7	12.5 mm (0.5")	09.5 mm (3/8")	2500,00		
8	09.5 mm (3/8")	06.3 mm (1/4")			
9	06.3 mm (1/4")	04.75 mm (4")			
10	04.75 mm (No.4)	02.36 mm (No.8)			
11	TOTAL SAMPLE WEIGHT (A)		5002,50	5002,50	
12	RETAINED ON SIEVE NO 12(B)		4788,50	3995,50	
13	ABRASION $100x\frac{(A-B)}{A}\times 100\%$		4,278	20,130	
17	Average Abrasion Loss (%)		12,20		

Yogyakarta, August 2025

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kusharjoto M.Eng, IEM., ASEAN.Eng.
NIK : 01 511 0101

Mengetahui
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 10 Specific Gravity Test of Fine Aggregate

SPECIFIC GRAVITY TEST OF FINE AGGREGATE

REFERENCE : SNI 1970 - 2008

1 Material Source : Clereng, Kulonprogo
2 Material Type : Fine Aggregate
3 Test Conducted in : 2025

No.	Description	Specimen		Average
		1	2	
1	Weight of SSD specimen (BJ) gr	500,01	500,04	
2	Weight of Pycnometer + Water (B) gr	647,04	681,31	
3	Weight of Pycnometer + Water + Sample (BT) gr	963,04	998,84	
4	Oven-Dry Weight of Sample (BK)	482,82	487,01	
5	Spec. Gravity (Bulk) = $\frac{BK}{(B+500)-BT}$	2,624	2,669	2,647
6	Spec. Gravity (SSD) = $\frac{500}{(B+500)-BT}$	2,717	2,740	2,729
7	Spec. Gravity (Apparent) = $\frac{BK}{(B+BK)-BT}$	2,894	2,874	2,884
8	Water Absorption = $\frac{(500-BK)}{BK} \times 100\%$	3,558	2,667	3,113
9	Effective Specific Gravity = (G bulk + G apparent)/2	2,559	2,771	2,665

Yogyakarta, August 2025

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, M.Eng, IPM., ASEAN.Eng.
NIK : 01 511 0101

Acknowledged by,
Head of Highway Engineering Lab.

Ir. Muhammad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 11 Sand Equivalent Test

SAND EQUIVALENT TEST

REFERENCE : SNI 3423-2008

1 Material Source : Clereng, Kulonprogo
2 Material Type : Fine Aggregate
3 Test Conducted in : 2025

No.	Description		Specimen 1	Specimen 2	Average
1	Preparation and soaking of specimens in $CaCl_2$ solution (±10.1 minutes)	Start	13.39	13.39	
		End	13.39	13.39	
2	Sedimentation time (after shaking specimen 90 times and adding $CaCl_2$ solution)	Start	13.44	13.44	
		End	13.59	13.59	
4	Clay reading (inches)		3,90	4,50	4,20
5	Sand reading (inches)		2,90	3,10	3,00
6	$Sand\ Eqiuvalent = \frac{Sand\ Reading}{Clay\ Reading} \times 100\ \%$		74,36	68,89	71,62
7	Clay Content = 100 - SE		25,64	31,11	28,38

Yogyakarta, August 2025

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berhan Kusbari, M.Eng, IPM., ASEAN.Eng.
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 13 Specific Gravity of Stone Dust Filler

SPECIFIC GRAVITY TEST OF GLASS POWDER FILLER

REFERENCE : SNI 2441-2011

1 Material Source : Pasuruan
2 Material Type : Glass Powder Filler
3 Test Conducted in : 2025

No.	Description	Specimen		Average
		1	2	
1	Weight of empty pycnometer gr	24,26	23,79	24,03
2	Weight of pycnometer + water gr	46,81	46,49	46,65
3	Weight of water (2-1) gr	22,55	22,70	22,63
4	Weight of pycnometer + filler gr	30,60	30,27	30,44
5	Weight of filler (4-1) gr	6,340	6,480	6,41
6	Weight of pycnometer + filler + water gr	50,470	50,220	50,35
7	Weight of water (6-4) gr	19,870	19,950	19,91
8	Volume of filler (3-7) gr	2,680	2,750	2,72
9	Specific gravity of filler = weight/vol (5/8)	2,366	2,356	2,361

Yogyakarta, August 2025

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, M.Eng, IPM., ASEAN.Eng.
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 14 Marshall Test Results

MARSHALL TEST RESULTS TO DETERMINE OPTIMUM ASPHALT CONTENT (OAC) USING ASPHALT PEN 60/70

Date of Testing: November 2024
Mixture Type: AC-BC

Sample	t (cm)	a (%)	b (%)	c (gram)	d (gram)	e (gram)	f (gram)	g	h	i	j	k	l VMA (%)	n VITM (%)	o	p	Thickness Corr.	q Stab. (kg)	r *Flow* (mm)
5%	64,63	5,26	5,00	1175,17	1183,94	668,97	514,97	2,282	2,423	10,971	83,192	5,837	16,81	5,84	76	1089,11	0,9718	1058,34	2,78
5%	69,03	5,26	5,00	1184,61	1191,76	661,02	530,74	2,232	2,423	10,731	81,368	7,901	18,63	7,90	82	1175,09	0,8900	1045,83	3,80
5%	67,03	5,26	5,00	1177,86	1183,65	655,40	528,25	2,230	2,423	10,720	81,286	7,994	18,71	7,99	78	1117,77	0,9218	1030,31	3,28
								2,248					**18,05**	**7,24**				**1044,83**	**3,29**
5,5%	67,05	5,82	5,50	1179,70	1185,72	665,03	520,69	2,266	2,407	11,982	82,160	5,858	17,84	5,86	83	1189,42	0,9213	1095,76	3,34
5,5%	65,83	5,82	5,50	1190,27	1198,44	675,69	522,75	2,277	2,407	12,042	82,570	5,389	17,43	5,39	86	1232,42	0,9463	1166,25	3,54
5,5%	66,86	5,82	5,50	1191,80	1202,13	664,42	537,71	2,216	2,407	11,722	80,376	7,903	19,62	7,90	79	1132,10	0,9260	1048,33	3,28
								2,253					**18,30**	**6,38**				**1103,45**	**3,39**
6%	67,83	6,38	6,00	1188,07	1194,98	668,28	526,70	2,256	2,390	13,014	81,366	5,620	18,63	5,62	89	1275,41	0,9018	1150,10	3,46
6%	65,20	6,38	6,00	1185,58	1194,38	669,54	524,84	2,259	2,390	13,032	81,483	5,484	18,52	5,48	88	1261,08	0,9581	1208,27	3,68
6%	67,23	6,38	6,00	1189,01	1201,85	678,16	523,69	2,270	2,390	13,099	81,899	5,003	18,10	5,00	98	1404,38	0,9168	1287,47	3,32
								2,262					**18,42**	**5,37**				**1215,28**	**3,49**
6,5%	65,26	6,95	6,50	1167,92	1173,80	659,27	514,53	2,270	2,374	14,187	81,443	4,371	18,56	4,37	88	1261,08	0,957	1206,85	3,53
6,5%	66,26	6,95	6,50	1184,61	1194,62	669,35	525,27	2,255	2,374	14,095	80,917	4,987	19,08	4,99	83	1189,42	0,938	1115,98	3,58
6,5%	65,20	6,95	6,50	1186,37	1200,76	675,67	525,09	2,259	2,374	14,121	81,065	4,814	18,93	4,81	78	1117,77	0,958	1070,97	3,72
								2,261					**18,86**	**4,72**				**1131,26**	**3,61**
7%	63,60	7,53	7,00	1190,31	1198,56	666,95	531,61	2,239	2,357	15,071	79,907	5,022	20,09	5,02	74	1060,45	0,9975	1057,80	3,91
7%	66,36	7,53	7,00	1158,52	1164,11	652,08	512,03	2,263	2,357	15,229	80,747	4,024	19,25	4,02	86	1232,42	0,9364	1154,00	3,71
7%	64,16	7,53	7,00	1170,21	1177,78	663,83	513,95	2,277	2,357	15,325	81,257	3,417	18,74	3,42	76	1089,11	0,9835	1071,14	3,73
								2,260					**19,36**	**4,15**				**1094,31**	**3,78**

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, M.Eng, IPM., ASEAN.Eng.
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhammad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

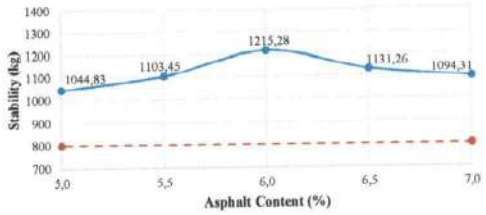
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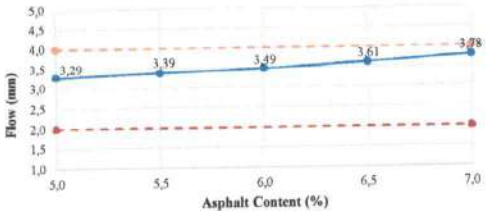
Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

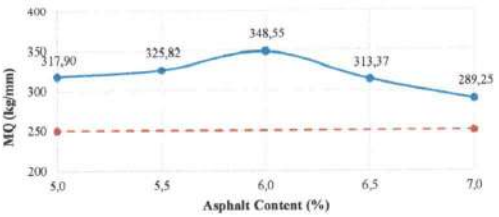
Appendix 15 Recapitulation of OAC Calculation

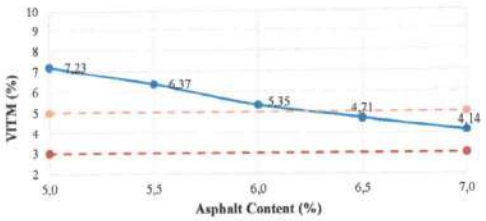
RECAPITULATION OF OPTIMUM ASPHALT CONTENT (OAC) CALCULATION

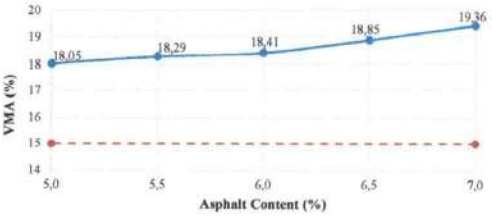
No.	Asphalt Content (%)	Marshall Stability (kg)	Flow (mm)	MQ (kg/mm)	VITM (%)	VMA (%)	VFWA (%)	Density (gr/cc)
1	5	1044,83	3,29	317,90	7,23	18,05	59,92	2,25
2	5,5	1103,45	3,39	325,82	6,37	18,29	65,17	2,25
3	6	1215,28	3,49	348,55	5,35	18,41	70,91	2,26
4	6,5	1131,26	3,61	313,37	4,71	18,85	75,02	2,26
5	7	1094,31	3,78	289,25	4,14	19,36	78,62	2,26
Specification		>800	2 - 4	>250	3 - 5	>14	>68	>2

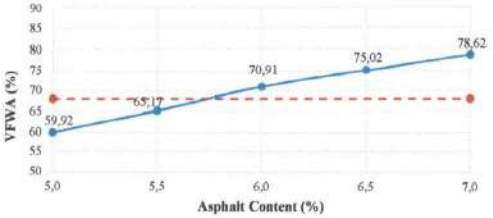


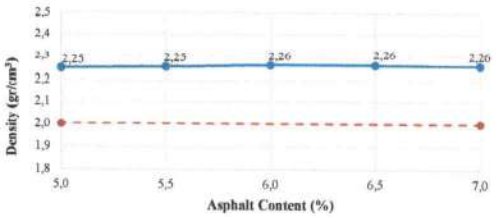


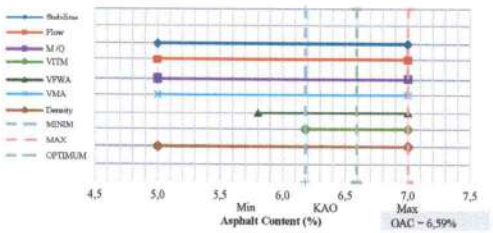












Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, M.Eng, IPM, ASEAN Eng
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

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FAKULTAS
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& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 16 Marshall Test Results with Substitution of Glass Powder Filler (0 Hour)

MARSHALL TEST RESULTS WITH SUBSTITUTION OF GLASS POWDER FILLER
0 Hours of Immersion

Date of Testing: February 2025
Mixture Type: AC-BC

Substitution (%)	t (cm)	a (%)	b (%)	c (gram)	d (gram)	e (gram)	f (gram)	g	h	i	j	k	l VMA (%)	m VFWA (%)	n VTIM (%)	o	p	Thickness Corr.	q Stab. (kg)	r *Flow* (mm)	MQ *(kg/mm)*
0	67,28	7,05	6,59	1202,20	1207,52	680,21	527,31	2,280	2,374	14,447	81,595	3,959	18,41	78,490	1,96	92	1318,40	0,9191	1211,69	2,98	406,61
0	65,67	7,05	6,59	1199,58	1204,24	679,47	524,77	2,286	2,374	14,485	81,811	3,704	18,19	79,634	1,70	95	1361,39	0,9458	1287,53	3,08	418,03
0	67,94	7,05	6,59	1201,55	1206,69	681,86	524,83	2,289	2,374	14,507	81,936	3,557	18,06	80,307	1,56	89	1275,41	0,8889	1133,73	3,12	363,38
								2,285					**18,22**	**79,48**	**1,74**				**1210,99**	**3,06**	**396,00**
25	66,54	7,05	6,59	1197,70	1204,87	674,05	530,82	2,256	2,372	14,297	80,842	4,861	19,16	74,627	4,86	84	1203,76	0,9239	1112,17	3,26	341,16
25	64,04	7,05	6,59	1201,03	1207,12	676,35	530,77	2,263	2,372	14,338	81,074	4,588	18,93	75,761	4,59	82	1175,09	0,9799	1151,52	3,28	351,07
25	65,11	7,05	6,59	1206,54	1210,23	684,87	525,36	2,297	2,372	14,552	82,285	3,163	17,72	82,147	3,16	81	1160,76	0,9599	1114,19	3,21	347,10
								2,272					**18,60**	**77,51**	**4,20**				**1125,96**	**3,25**	**346,44**
50	64,21	7,05	6,59	1203,65	1207,67	682,52	525,15	2,292	2,369	14,523	82,212	3,264	17,79	81,648	3,26	85	1218,09	0,9823	1196,46	3,09	387,21
50	66,07	7,05	6,59	1195,92	1206,89	678,14	528,75	2,262	2,369	14,332	81,128	4,540	18,87	75,943	4,54	84	1203,76	0,9358	1126,41	3,07	366,91
50	65,79	7,05	6,59	1204,78	1208,39	683,73	524,66	2,296	2,369	14,551	82,366	3,083	17,63	82,516	3,08	81	1160,76	0,9470	1099,24	3,15	348,97
								2,283					**18,10**	**80,04**	**3,63**				**1140,71**	**3,10**	**367,69**
75	68,92	7,05	6,59	1202,67	1211,51	685,86	525,65	2,288	2,367	14,498	82,159	3,343	17,84	81,261	3,34	88	1261,08	0,890	1122,36	3,03	370,42
75	64,33	7,05	6,59	1194,82	1208,55	686,34	522,21	2,288	2,367	14,498	82,160	3,342	17,84	81,269	3,34	92	1318,40	0,979	1290,93	3,05	423,26
75	65,70	7,05	6,59	1205,38	1210,73	682,37	528,36	2,281	2,367	14,456	81,922	3,622	18,08	79,963	3,62	95	1361,39	0,949	1291,53	2,99	431,95
								2,286					**17,92**	**80,83**	**3,44**				**1234,94**	**3,02**	**408,54**
100	65,82	7,05	6,59	1207,65	1213,36	678,50	534,86	2,258	2,365	14,307	81,169	4,524	18,83	75,978	4,52	81	1160,76	0,9466	1098,74	3,65	301,02
100	65,72	7,05	6,59	1194,63	1202,35	677,19	525,16	2,275	2,365	14,414	81,777	3,808	18,22	79,101	3,81	80	1146,43	0,9484	1087,25	3,45	315,14
100	64,92	7,05	6,59	1201,07	1208,19	673,71	534,48	2,247	2,365	14,239	80,784	4,976	19,22	74,103	4,98	78	1117,77	0,9634	1076,90	3,54	304,21
								2,260					**18,76**	**76,39**	**4,44**				**1087,63**	**3,55**	**306,79**

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, M.Eng., IPM., ASEAN.Eng.
ASEAN.01.511.0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

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FAKULTAS
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& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 17 Marshall Test Results with Substitution of Glass Powder Filler (24 Hour)

MARSHALL TEST RESULTS WITH SUBSTITUTION OF GLASS POWDER FILLER
24 Hours of Immersion

Date of Testing: March 2025
Mixture Type: AC-BC

Substitution (%)	t (cm)	a (%)	b (%)	c (gram)	d (gram)	e (gram)	f (gram)	g	h	i	j	k	l VMA (%)	m VFWA (%)	n VITM (%)	o	p	Thickness Corr.	q Stab. (kg)	r Flow (mm)	MQ (kg/mm)
0	66,03	7,05	6,59	1200,84	1206,31	681,12	525,19	2,286	2,374	14,488	81,831	3,680	18,17	79,743	3,68	83	1189,42	0,9425	1121,03	3,45	324,94
0	66,69	7,05	6,59	1201,73	1206,21	680,52	525,69	2,286	2,374	14,485	81,814	3,701	18,19	79,651	3,70	82	1175,09	0,9303	1093,23	3,46	315,96
0	65,92	7,05	6,59	1200,95	1205,32	679,83	525,49	2,285	2,374	14,481	81,792	3,727	18,21	79,534	3,73	86	1232,42	0,9446	1164,09	3,58	325,17
								2,286					**18,19**	**79,64**	**3,70**				**1126,12**	**3,50**	**322,02**
25	67,71	7,05	6,59	1198,07	1205,08	675,82	529,26	2,264	2,372	14,344	81,105	4,551	18,89	75,913	4,55	77	1103,44	0,9047	998,25	3,61	276,52
25	66,01	7,05	6,59	1200,89	1206,11	681,73	524,38	2,290	2,372	14,511	82,052	3,436	17,95	80,855	3,44	79	1132,10	0,9429	1067,50	3,65	292,47
25	67,20	7,05	6,59	1204,01	1209,65	675,75	533,90	2,255	2,372	14,290	80,799	4,912	19,20	74,421	4,91	81	1160,76	0,9176	1065,10	3,70	287,86
								2,270					**18,68**	**77,06**	**4,30**				**1043,62**	**3,65**	**285,62**
50	68,50	7,05	6,59	1199,25	1204,35	680,66	523,69	2,290	2,369	14,511	82,140	3,349	17,86	81,247	3,35	82	1175,09	0,8900	1045,83	3,48	300,53
50	67,07	7,05	6,59	1196,28	1200,32	677,73	522,59	2,289	2,369	14,505	82,109	3,386	17,89	81,076	3,39	77	1103,44	0,9208	1016,09	3,42	297,10
50	67,93	7,05	6,59	1200,14	1207,57	679,82	527,75	2,274	2,369	14,410	81,569	4,022	18,43	78,180	4,02	89	1275,41	0,8993	1147,02	3,45	332,47
								2,284					**18,06**	**80,17**	**3,59**				**1069,65**	**3,45**	**310,03**
75	66,44	7,05	6,59	1201,38	1206,82	681,63	525,19	2,288	2,367	14,495	82,143	3,362	17,86	81,171	3,36	87	1246,75	0,935	1165,63	3,39	343,84
75	69,03	7,05	6,59	1196,16	1201,02	679,76	521,26	2,295	2,367	14,541	82,402	3,057	17,60	82,629	3,06	86	1232,42	0,890	1096,85	3,31	331,37
75	67,38	7,05	6,59	1202,43	1207,23	678,68	528,55	2,275	2,367	14,415	81,692	3,893	18,31	78,737	3,89	90	1289,74	0,917	1183,09	3,35	353,16
								2,286					**17,92**	**80,85**	**3,44**				**1148,52**	**3,35**	**342,79**
100	65,00	7,05	6,59	1197,96	1202,30	672,51	529,79	2,261	2,365	14,328	81,289	4,383	18,71	76,574	4,38	72	1031,79	0,9626	993,18	3,85	257,97
100	68,11	7,05	6,59	1201,65	1206,96	675,65	531,31	2,262	2,365	14,331	81,306	4,363	18,69	76,660	4,36	80	1146,43	0,8900	1020,33	3,94	258,97
100	66,08	7,05	6,59	1199,26	1204,52	674,23	530,29	2,262	2,365	14,330	81,300	4,370	18,70	76,632	4,37	75	1074,78	0,9416	1011,97	3,88	260,82
								2,261					**18,70**	**76,62**	**4,37**				**1008,49**	**3,89**	**259,25**

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, M.Eng., PM., ASEAN.Eng.
NIK : 91 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

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& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 18 Marshall Test Results with Substitution of Glass Powder Filler (48 Hour)

MARSHALL TEST RESULTS WITH SUBSTITUTION OF GLASS POWDER FILLER
48 Hours of Immersion

Date of Testing: March 2025
Mixture Type: AC-BC

Substitution (%)	t (cm)	a (%)	b (%)	c (gram)	d (gram)	e (gram)	f (gram)	g	h	i	j	k	l VMA (%)	m VFWA (%)	n VITM (%)	o	p	Thickness Corr.	q Stab. (kg)	r *Flow* (mm)	MQ *(kg/mm)*
0	63,22	7,05	6,59	1199,05	1203,07	676,05	527,02	2,275	2,374	14,417	81,426	4,158	18,57	77,615	4,16	74	1060,45	1,0071	1067,96	4,05	263,69
0	68,07	7,05	6,59	1195,13	1194,54	678,37	516,17	2,315	2,374	14,671	82,865	2,463	17,13	85,625	2,46	76	1089,11	0,8950	974,71	3,92	248,65
0	65,79	7,05	6,59	1197,38	1201,23	672,54	528,69	2,265	2,374	14,351	81,055	4,594	18,94	75,752	4,59	78	1117,77	0,9471	1058,67	3,85	274,98
								2,285					**18,22**	**79,66**	**3,74**				**1033,78**	**3,94**	**262,44**
25	67,70	7,05	6,59	1190,81	1196,11	671,04	525,07	2,268	2,372	14,371	81,257	4,372	18,74	76,672	4,37	75	1074,78	0,9050	972,68	4,15	234,38
25	67,08	7,05	6,59	1197,98	1204,21	673,56	530,65	2,258	2,372	14,305	80,886	4,808	19,11	74,843	4,81	78	1117,77	0,9204	1028,82	4,07	252,78
25	67,27	7,05	6,59	1202,74	1207,71	681,97	525,74	2,288	2,372	14,496	81,966	3,538	18,03	80,384	3,54	72	1031,79	0,9158	944,95	4,18	226,06
								2,271					**18,63**	**77,30**	**4,24**				**982,15**	**4,13**	**237,74**
50	66,37	7,05	6,59	1197,76	1203,75	678,93	524,82	2,282	2,369	14,461	81,861	3,677	18,14	79,727	3,68	75	1074,78	0,9383	1008,41	3,48	289,77
50	66,44	7,05	6,59	1200,89	1208,26	680,84	527,42	2,277	2,369	14,428	81,671	3,902	18,33	78,714	3,90	71	1017,46	0,9349	951,20	3,87	245,79
50	65,99	7,05	6,59	1204,07	1210,73	684,26	526,47	2,287	2,369	14,492	82,035	3,473	17,97	80,667	3,47	78	1117,77	0,9433	1054,34	4,14	254,67
								2,282					**18,14**	**79,70**	**3,68**				**1004,65**	**3,83**	**263,41**
75	66,87	7,05	6,59	1201,06	1209,26	684,93	524,33	2,291	2,367	14,515	82,255	3,230	17,74	81,799	3,23	79	1132,10	0,927	1049,18	3,89	269,71
75	67,95	7,05	6,59	1203,27	1210,01	684,11	525,90	2,288	2,367	14,498	82,161	3,341	17,84	81,271	3,34	84	1203,76	0,890	1071,34	3,61	296,77
75	67,52	7,05	6,59	1198,45	1203,17	677,78	525,39	2,281	2,367	14,454	81,911	3,635	18,09	79,906	3,63	80	1146,43	0,910	1042,78	3,50	297,94
								2,287					**17,89**	**80,99**	**3,40**				**1054,43**	**3,67**	**288,14**
100	67,83	7,05	6,59	1191,99	1198,92	671,12	527,80	2,258	2,365	14,311	81,188	4,501	18,81	76,073	4,50	65	931,48	0,8900	829,01	4,65	178,28
100	65,77	7,05	6,59	1193,10	1200,87	673,85	527,02	2,264	2,365	14,345	81,384	4,271	18,62	77,059	4,27	70	1003,13	0,9474	950,40	4,36	217,98
100	65,21	7,05	6,59	1199,83	1204,78	672,95	531,83	2,256	2,365	14,295	81,103	4,601	18,90	75,650	4,60	69	988,80	0,9672	956,33	3,80	251,67
								2,259					**18,77**	**76,26**	**4,46**				**911,92**	**4,27**	**215,98**

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Bernah Kusbiantoro Ad Rad, IPM., ASEAN.Eng.
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

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FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

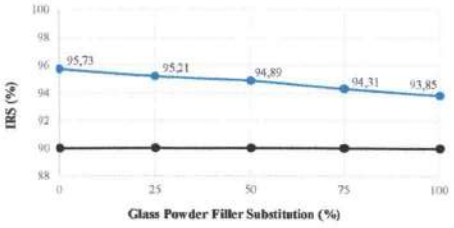
Appendix 19 IRS Test Results and Recapitulation (0 Hour)

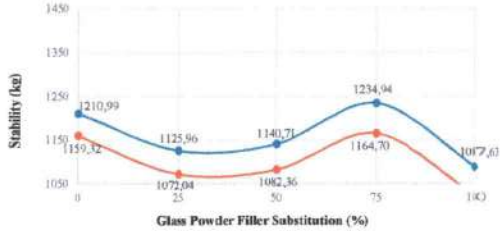
IRS TEST RESULTS
0 Hours of Immersion

Filler Substitution		Sample Thickness (mm)				Corr.	Stability Dial Gauuge			Stability (kg)			Thickness Correction			
													Sample Thickness		Correction	
		1	2	3	Average		Meas	Calibration	Adjust	Initial	Avg.	Min.	MIN	MAX	MIN	MAX
0%	1	63,40	64,00	63,50	63,63	1,00	82	31,56	2588,31	1170,15	1159,32	800	63,5	65,1	1	0,96
	2	64,30	64,50	64,50	64,43	0,98	83	31,56	2619,88	1160,65			61,9	63,5	1,04	1
	3	64,10	64,40	63,30	63,93	0,99	81	31,56	2556,75	1147,18			63,5	65,1	1	0,96
25%	1	65,00	64,10	66,40	65,17	0,96	74	31,56	2335,80	1015,37	1032,80	800	63,5	65,1	1	0,96
	2	63,80	63,40	64,10	63,77	0,99	77	31,56	2430,49	1092,57			63,5	54	1	1,32
	3	64,50	63,70	63,50	63,90	0,89	78	31,56	2462,05	990,45			52,4	54	1,39	1,32
50%	1	62,70	61,90	64,80	63,13	1,00	75	31,56	2367,36	1070,48	1037,12	800	65,1	66,7	0,96	0,93
	2	65,40	64,40	64,60	64,80	0,85	79	31,56	2493,62	958,61			52,4	54	1,39	1,32
	3	64,50	63,80	64,40	64,23	0,98	77	31,56	2430,49	1082,26			63,5	65,1	1	0,96
75%	1	66,60	67,10	67,30	67,00	0,91	86	31,56	2714,57	1123,59	1164,70	800	63,5	65,1	1	0,96
	2	67,70	67,40	67,10	67,40	0,90	91	31,56	2872,40	1175,88			63,5	65,1	1	0,96
	3	66,00	65,60	66,40	66,00	0,94	89	31,56	2809,27	1194,64			63,5	65,1	1	0,96
100%	1	62,30	61,60	61,30	61,73	1,02	72	31,56	2272,67	1054,72	1020,78	800	65,1	66,7	0,96	0,93
	2	63,30	62,50	63,20	63,00	1,00	70	31,56	2209,54	1001,62			65,1	66,7	0,96	0,93
	3	65,10	64,60	65,20	64,97	0,96	73	31,56	2304,23	1006,00			65,1	66,7	0,96	0,93

RECAPITULATION OF IRS TEST

Filler Substitution (%)	OAC (%)	Stability 0 Hour	Stability 24 Hour	IRS
0	6,59	1210,99	1159,32	95,73
25		1125,96	1072,04	95,21
50		1140,71	1082,36	94,89
75		1234,94	1164,70	94,31
100		1087,63	1020,78	93,85





Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Bernadin Kurniadi, M.Eng, IPM, ASEAN Eng.
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS TEKNIK SIPIL & PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

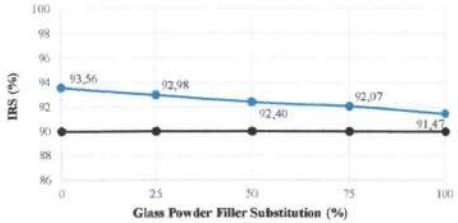
Appendix 20 IRS Test Results and Recapitulation (24 Hour)

IRS TEST RESULTS
24 Hours of Immersion

Filler Substitution		Sample Thickness (mm)				Corr.	Stability Dial Gauuge			Stability (kg)			Thickness Correction			
													Sample Thickness		Correction	
		1	2	3	Average		Meas	Calibration	Adjust	Initial	Avg.	Min.	MIN	MAX	MIN	MAX
0%	1	65,30	65,10	64,80	65,07	0,96	79	31,56	2493,62	1086,80	1053,55	800	63,5	65,1	1	0,96
	2	63,60	64,50	65,10	64,40	0,97	74	31,56	2335,80	1031,04			65,1	66,7	0,96	0,93
	3	65,20	65,20	65,10	65,17	0,96	76	31,56	2398,92	1042,81			63,5	65,1	1	0,96
25%	1	64,80	64,20	63,90	64,30	0,98	67	31,56	2114,84	935,31	970,31	800	65,1	66,7	0,96	0,93
	2	62,20	62,10	63,10	62,47	1,01	69	31,56	2177,97	997,19			65,1	66,7	0,96	0,93
	3	64,80	64,90	65,20	64,97	0,96	71	31,56	2241,10	978,44			65,1	66,7	0,96	0,93
50%	1	64,50	64,20	63,30	64,00	0,98	72	31,56	2272,67	1010,91	988,39	800	65,1	66,7	0,96	0,93
	2	63,70	64,10	64,50	64,10	0,98	69	31,56	2177,97	966,93			65,1	66,7	0,96	0,93
	3	64,70	64,50	64,30	64,50	0,97	71	31,56	2241,10	987,34			65,1	66,7	0,96	0,93
75%	1	64,60	65,40	66,00	65,33	0,95	76	31,56	2398,92	1038,28	1057,39	800	61,9	63,5	1,04	1
	2	63,50	63,40	62,50	63,13	1,00	74	31,56	2335,80	1056,21			65,1	66,7	0,96	0,93
	3	64,30	65,00	65,20	64,83	0,97	78	31,56	2462,05	1077,70			65,1	66,7	0,96	0,93
100%	1	64,00	64,20	64,00	64,07	0,98	65	31,56	2051,71	911,46	922,48	800	65,1	66,7	0,96	0,93
	2	63,80	62,40	63,10	63,10	1,01	67	31,56	2114,84	968,89			63,5	65,1	1	0,96
	3	66,30	66,60	65,80	66,23	0,94	66	31,56	2083,28	887,09			65,1	66,7	0,96	0,93

RECAPITULATION OF IRS TEST

Filler Substitution (%)	OAC (%)	Stability 0 Hour	Stability 24 Hour	IRS
0	6,59	1126,12	1053,55	93,56
25		1043,62	970,31	92,98
50		1069,65	988,39	92,40
75		1148,52	1057,39	92,07
100		1008,49	922,48	91,47





Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, MEng, IPM, ASEAN.Eng.
NIK. 01 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

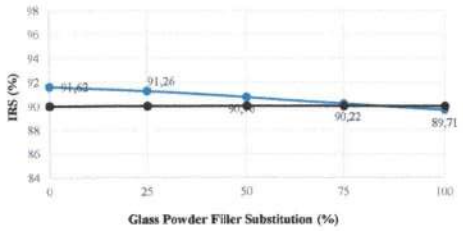
Appendix 21 IRS Test Results and Recapitulation (48 Hour)

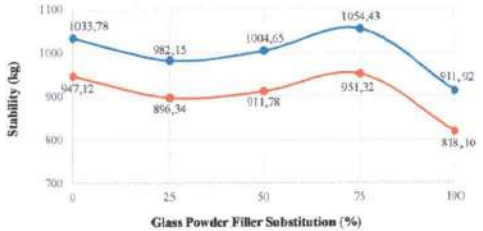
IRS TEST RESULTS
48 Hours of Immersion

Filler Substitution		Sample Thickness (mm)				Corr.	Stability Dial Gauuge			Stability (kg)			Thickness Correction			
													Sample Thickness		Correction	
		1	2	3	Average		Meas	Calibration	Adjust	Initial	Avg.	Min.	MIN	MAX	MIN	MAX
0%	1	64,40	65,20	65,10	64,90	0,97	69	31,56	2177,97	953,35	947,12	800	63,5	65,1	1	0,96
	2	63,20	63,60	64,70	63,83	0,99	68	31,56	2146,41	965,50			63,5	65,1	1	0,96
	3	65,10	65,20	64,80	65,03	0,96	67	31,56	2114,84	922,52			63,5	65,1	1	0,96
25%	1	66,30	64,40	65,00	65,23	0,96	63	31,56	1988,58	863,69	896,34	800	65,1	66,7	0,96	0,93
	2	65,50	65,80	62,80	64,70	0,97	64	31,56	2020,15	888,85			63,5	65,1	1	0,96
	3	64,70	65,20	65,10	65,00	0,96	68	31,56	2146,41	936,49			65,1	66,7	0,96	0,93
50%	1	66,20	65,10	66,30	65,87	0,95	67	31,56	2114,84	907,13	911,78	800	65,1	66,7	0,96	0,93
	2	64,60	65,50	65,40	65,17	0,96	68	31,56	2146,41	933,45			65,1	66,7	0,96	0,93
	3	66,30	65,40	65,70	65,80	0,95	66	31,56	2083,28	894,77			65,1	66,7	0,96	0,93
75%	1	65,30	65,40	66,20	65,63	0,95	70	31,56	2209,54	952,13	951,32	800	65,1	66,7	0,96	0,93
	2	65,00	66,30	66,20	65,83	0,95	69	31,56	2177,97	934,83			65,1	66,7	0,96	0,93
	3	65,40	65,10	66,20	65,57	0,95	71	31,56	2241,10	967,01			65,1	66,7	0,96	0,93
100%	1	64,40	65,70	64,20	64,77	0,97	62	31,56	1957,02	859,59	818,10	800	63,5	65,1	1	0,96
	2	66,30	67,20	67,50	67,00	0,92	58	31,56	1830,76	766,07			66,7	68,3	0,93	0,89
	3	65,30	64,80	67,00	65,70	0,95	61	31,56	1925,45	828,62			65,1	66,7	0,96	0,93

RECAPITULATION OF IRS TEST

Filler Substitution (%)	OAC (%)	Stability 0 Hour	Stability 24 Hour	IRS
0	6,59	1033,78	947,12	91,62
25		982,15	896,34	91,26
50		1004,65	911,78	90,76
75		1054,43	951,32	90,22
100		911,92	818,10	89,71





Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, MEng, IPM, ASEAN.Eng.
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

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Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 22 ITS Test Results (0 Hour)

ITS TEST RESULTS
0 Hour of Immersion

Asphalt Optimum Content	Filler Substitution (%)		Sample Thickness (mm)				Corr.	Sample Diameter (Inch)				Stability Dial Gauge			Stability (kg)			Thickness Correction				ITS 0 Hour kPa		
			1	2	3	Avg		1	2	3	Avg	Meas	Calibration	Adjust	Initial	Avg	Min	Sample Thickness MIN	Sample Thickness MAX	Correction MIN	Correction MAX	Initial	Avg	Min
6,59%	0%	1	66,19	66,11	65,67	65,99	0,94	3,99	3,99	3,96	3,98	11	14,33	157,63	147,82	156,36	800	63,5	65,1	1	0,96	138,34	148,74	800
		2	63,05	63,18	65,48	63,90	0,98	3,98	3,92	3,99	3,96	10	14,33	143,30	140,79			65,1	66,7	0,96	0,93	136,63		
		3	64,23	65,80	64,23	64,75	0,97	3,99	4,01	4,00	4,00	13	14,33	186,30	180,46			63,5	65,1	1	0,96	171,25		
	25%	1	63,11	62,82	63,38	63,10	1,01	3,99	4,00	3,93	3,97	13	14,33	186,30	188,14	146,03	800	63,5	65,1	1	0,96	184,44	139,77	800
		2	64,41	64,60	64,46	64,49	0,99	4,07	4,04	4,05	4,05	10	14,33	143,30	141,19			66,7	68,3	0,93	0,89	132,76		
		3	65,80	65,21	66,12	65,71	0,95	3,97	3,99	3,99	3,98	8	14,33	114,64	108,75			65,1	66,7	0,96	0,93	102,12		
	50%	1	66,34	66,05	65,60	66,00	0,94	3,99	3,96	3,98	3,98	9	14,33	128,97	121,65	151,43	800	65,1	66,7	0,96	0,93	113,93	143,28	800
		2	64,43	64,07	62,05	63,52	0,99	3,98	4,00	4,03	4,00	11	14,33	157,63	156,01			65,1	66,7	0,96	0,93	150,80		
		3	65,70	66,31	65,20	65,74	0,95	4,00	3,99	4,01	4,00	13	14,33	186,30	176,62			65,1	66,7	0,96	0,93	165,10		
	75%	1	64,64	63,59	63,16	63,80	0,99	4,00	4,04	4,04	4,03	12	14,33	171,97	170,69	157,20	800	63,5	65,1	1	0,96	163,32	149,09	800
		2	66,02	65,96	65,64	65,87	0,95	3,98	3,97	3,99	3,98	11	14,33	157,63	149,04			65,1	66,7	0,96	0,93	139,73		
		3	64,75	65,10	65,05	64,97	0,96	3,98	4,00	3,97	3,98	11	14,33	157,63	151,85			63,5	65,1	1	0,96	144,23		
	100%	1	65,07	64,94	63,95	64,65	0,97	4,05	4,04	4,05	4,05	11	14,33	157,63	152,65	133,68	800	65,1	66,7	0,96	0,93	143,41	126,00	800
		2	65,92	64,68	64,53	65,04	0,96	4,02	4,02	4,02	4,02	11	14,33	157,63	151,55			63,5	65,1	1	0,96	142,46		
		3	64,82	64,50	65,10	64,81	0,97	3,96	4,00	4,00	3,99	7	14,33	100,31	96,85			65,1	66,7	0,96	0,93	92,14		

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Bernad Kusnadi, M.Eng, IPM., ASEAN.Eng.
NIK : 01511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhammad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

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Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 23 ITS Test Results (24 Hour)

ITS TEST RESULTS
24 Hour of Immersion

Asphalt Optimum Content	Filler Substitution (%)		Sample Thickness (mm)				Corr.	Sample Diameter (Inch)				Stability Dial Gauge			Stability (kg)			Thickness Correction				ITS 0 Hour kPa		
			1	2	3	Avg		1	2	3	Avg	Meas	Calibration	Adjust	Initial	Avg	Min	Sample Thickness MIN	Sample Thickness MAX	Correction MIN	Correction MAX	Initial	Avg	Min
6,59%	0%	1	63,08	63,54	63,21	63,28	1,01	4,01	4,01	3,98	4,00	10	14,33	143,30	144,10	144,02	800	63,5	65,1	1	0,96	139,94	137,13	800
		2	65,20	65,22	65,80	65,41	0,95	3,98	3,99	4,00	3,99	9	14,33	128,97	123,07			65,1	66,7	0,96	0,93	115,95		
		3	64,80	65,10	65,58	65,16	0,96	3,97	4,03	4,00	4,00	12	14,33	171,97	164,89			65,1	66,7	0,96	0,93	155,50		
	25%	1	62,83	62,64	62,79	62,75	1,03	4,10	4,07	4,05	4,07	9	14,33	128,97	132,67	133,07	800	66,7	68,3	0,93	0,89	127,57	127,50	800
		2	64,80	66,12	65,21	65,38	0,96	3,93	4,00	3,99	3,97	8	14,33	114,64	110,41			66,7	68,3	0,93	0,89	104,47		
		3	63,86	64,02	63,76	63,88	0,99	3,97	3,99	4,02	3,99	11	14,33	157,63	156,14			63,5	65,1	1	0,96	150,44		
	50%	1	62,15	63,00	62,54	62,56	1,03	4,07	4,04	4,01	4,04	9	14,33	128,97	133,28	138,11	800	66,7	68,3	0,93	0,89	129,61	130,46	800
		2	67,82	68,16	67,58	67,85	0,90	3,97	3,98	3,97	3,97	11	14,33	157,63	142,06			66,7	68,3	0,93	0,89	129,51		
		3	64,25	65,34	64,12	64,57	0,97	4,00	4,02	3,98	4,00	10	14,33	143,30	139,00			65,1	66,7	0,96	0,93	132,28		
	75%	1	65,93	64,18	63,21	64,44	0,99	4,02	3,98	3,97	3,99	10	14,33	143,30	141,37	146,59	800	66,7	68,3	0,93	0,89	135,14	138,03	800
		2	67,23	66,89	67,46	67,19	0,92	3,98	4,00	3,97	3,98	9	14,33	128,97	118,35			66,7	68,3	0,93	0,89	108,68		
		3	63,97	64,50	65,80	64,76	0,97	4,04	3,99	4,01	4,01	13	14,33	186,30	180,04			65,1	66,7	0,96	0,93	170,28		
	100%	1	62,02	62,04	62,51	62,19	1,04	4,08	4,04	4,05	4,06	9	14,33	128,97	134,49	122,34	800	66,7	68,3	0,93	0,89	131,03	116,44	800
		2	64,28	65,08	65,23	64,86	0,97	4,04	4,00	4,01	4,02	9	14,33	128,97	124,58			63,5	65,1	1	0,96	117,53		
		3	65,87	65,35	66,27	65,83	0,94	3,99	4,01	4,00	4,00	8	14,33	114,64	107,97			63,5	65,1	1	0,96	100,78		

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Bachan Kushari, M.Eng, IPM., ASEAN Eng.
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

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Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 24 ITS Test Results (48 Hour)

ITS TEST RESULTS
48 Hour of Immersion

Asphalt Optimum Content	Filler Substitution (%)		Sample Thickness (mm)				Corr.	Sample Diameter (Inch)				Stability Dial Gauge			Stability (kg)			Thickness Correction				ITSO Hour kPa		
			1	2	3	Avg		1	2	3	Avg	Meas	Calibration	Adjust	Initial	Avg	Min	Sample Thickness MIN	Sample Thickness MAX	Correction MIN	Correction MAX	Initial	Avg	Min
6,59%	0%	1	64,55	65,48	64,25	64,76	0,97	3,99	3,96	3,98	3,98	11	14,33	157,63	152,33	129,06	800	65,1	66,7	0,96	0,93	145,39	122,57	800
		2	65,80	64,97	64,60	65,12	0,96	4,01	4,00	4,00	4,00	10	14,33	143,30	137,49			63,5	65,1	1	0,96	129,62		
		3	64,87	64,95	64,23	64,68	0,97	3,99	3,98	4,00	3,99	7	14,33	100,31	97,35			63,5	65,1	1	0,96	92,71		
	25%	1	63,38	62,98	62,79	63,05	1,00	4,02	4,04	4,01	4,02	8	14,33	114,64	114,46	121,18	800	65,1	66,7	0,96	0,93	110,91	116,05	800
		2	64,76	65,08	64,94	64,93	0,96	3,98	3,96	3,98	3,97	11	14,33	157,63	152,01			63,5	65,1	1	0,96	144,83		
		3	65,00	64,80	64,60	64,80	0,97	3,97	3,98	4,00	3,98	7	14,33	100,31	97,05			63,5	65,1	1	0,96	92,42		
	50%	1	63,61	64,57	63,75	63,98	0,98	4,00	4,00	4,00	4,00	7	14,33	100,31	98,41	128,92	800	65,1	66,7	0,96	0,93	94,52	121,45	800
		2	64,86	64,20	64,40	64,49	0,98	4,02	4,00	4,01	4,01	11	14,33	157,63	153,75			63,5	65,1	1	0,96	146,14		
		3	66,36	65,95	66,30	66,20	0,94	4,05	4,04	4,03	4,04	10	14,33	143,30	134,61			65,1	66,7	0,96	0,93	123,70		
	75%	1	64,52	63,97	65,04	64,51	0,97	3,98	4,00	4,00	3,99	12	14,33	171,97	167,62	130,18	800	63,5	65,1	1	0,96	159,93	124,80	800
		2	63,80	62,87	64,02	63,56	0,99	4,00	3,98	3,97	3,98	8	14,33	114,64	113,36			65,1	66,7	0,96	0,93	110,05		
		3	65,45	64,10	66,28	65,28	0,96	3,94	3,96	3,95	3,95	8	14,33	114,64	109,55			63,5	65,1	1	0,96	104,43		
	100%	1	62,73	64,89	66,53	64,72	0,97	4,05	4,00	4,05	4,03	9	14,33	128,97	124,74	110,93	800	65,1	66,7	0,96	0,93	117,46	104,32	800
		2	64,23	64,75	64,50	64,49	0,98	4,06	4,04	4,05	4,05	8	14,33	114,64	111,80			63,5	65,1	1	0,96	105,20		
		3	65,10	64,96	65,32	65,13	0,96	4,01	4,03	4,03	4,02	7	14,33	100,31	96,25			65,1	66,7	0,96	0,93	90,29		

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, M.Eng, IPM., ASEAN.Eng.
NIK : 21 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

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Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 25 TSR Test Results (0 Hour)

TSR TEST RESULTS
0 Hour of Immersion

Asphalt Optimum Content	Filler Substitution (%)		Sample Thickness (mm)				Corr.	Sample Diameter (Inch)				Stability Dial Gauge			Stability (kg)			Thickness Correction				ITSO Hour kPa		
			1	2	3	Avg		1	2	3	Avg	Meas	Calibration	Adjust	Initial	Avg	Min	Sample Thickness MIN	Sample Thickness MAX	Correction MIN	Correction MAX	Initial	Avg	Min
6,59%	0%	1	66,41	66,81	66,32	66,51	0,92	4,06	4,00	3,99	4,02	11	14,33	157,63	145,76	138,66	800	63,5	65,1	1	0,96	134,10	131,29	800
		2	62,56	62,81	62,07	62,48	1,03	4,05	4,01	4,05	4,04	9	14,33	128,97	132,26			61,9	63,5	1,04	1	128,90		
		3	64,80	65,23	64,95	64,99	0,96	3,99	4,00	3,97	3,99	10	14,33	143,30	137,95			63,5	65,1	1	0,96	130,86		
	25%	1	64,14	64,21	63,77	64,04	0,99	4,01	4,01	4,00	4,01	10	14,33	143,30	141,37	129,39	800	63,5	65,1	1	0,96	135,42	122,05	800
		2	64,91	65,31	65,43	65,22	0,96	4,00	4,02	4,00	4,01	9	14,33	128,97	123,44			63,5	65,1	1	0,96	116,12		
		3	65,55	65,20	65,10	65,28	0,96	4,04	4,06	4,06	4,05	9	14,33	128,97	123,37			65,1	66,7	0,96	0,93	114,60		
	50%	1	65,13	65,92	65,43	65,49	0,95	3,99	3,96	3,99	3,98	10	14,33	143,30	136,16	129,48	800	63,5	65,1	1	0,96	128,39	123,78	800
		2	64,33	64,66	63,00	64,00	0,98	3,98	4,00	4,00	3,99	11	14,33	157,63	154,59			65,1	66,7	0,96	0,93	148,68		
		3	64,50	65,14	64,00	64,55	0,97	3,96	3,93	3,95	3,95	7	14,33	100,31	97,69			63,5	65,1	1	0,96	94,25		
	75%	1	65,23	65,71	65,43	65,46	0,95	3,99	3,98	3,99	3,99	10	14,33	143,30	136,29	132,86	800	63,5	65,1	1	0,96	128,38	125,97	800
		2	65,24	64,57	65,22	65,01	0,96	3,99	4,00	3,98	3,99	11	14,33	157,63	151,60			65,1	66,7	0,96	0,93	143,65		
		3	64,30	64,65	65,70	64,88	0,97	3,97	3,96	3,95	3,96	8	14,33	114,64	110,68			63,5	65,1	1	0,96	105,88		
	100%	1	64,68	65,18	64,57	64,81	0,97	4,01	4,00	4,00	4,00	7	14,33	100,31	96,85	106,78	800	65,1	66,7	0,96	0,93	91,72	101,49	800
		2	64,29	64,94	65,76	65,00	0,96	4,00	3,99	3,98	3,99	9	14,33	128,97	124,15			63,5	65,1	1	0,96	117,66		
		3	64,00	64,23	63,42	63,88	0,99	4,00	4,02	4,04	4,02	7	14,33	100,31	99,35			63,5	65,1	1	0,96	95,09		

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Bushari, M.Eng, IPM., ASEAN.Eng.
NIK. 01 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhammad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 26 ITS Test Results (24 Hour)

ITS TEST RESULTS
24 Hour of Immersion

Asphalt Optimum Content	Filler Substitution (%)		Sample Thickness (mm)				Corr.	Sample Diameter (Inch)				Stability Dial Gauge			Stability (kg)			Thickness Correction				ITS 0 Hour kPa		
			1	2	3	Avg		1	2	3	Avg	Meas	Calibration	Adjust	Initial	Avg	Min	Sample Thickness MIN	Sample Thickness MAX	Correction MIN	Correction MAX	Initial	Avg	Min
6,59%	0%	1	63,08	63,54	63,21	63,28	1,01	4,01	4,01	3,98	4,00	10	14,33	143,30	144,10	144,02	800	63,5	65,1	1	0,96	139,94	137,13	800
		2	65,20	65,22	65,80	65,41	0,95	3,98	3,99	4,00	3,99	9	14,33	128,97	123,07			65,1	66,7	0,96	0,93	115,95		
		3	64,80	65,10	65,58	65,16	0,96	3,97	4,03	4,00	4,00	12	14,33	171,97	164,89			65,1	66,7	0,96	0,93	155,50		
	25%	1	62,83	62,64	62,79	62,75	1,03	4,10	4,07	4,05	4,07	9	14,33	128,97	132,67	133,07	800	66,7	68,3	0,93	0,89	127,57	127,50	800
		2	64,80	66,12	65,21	65,38	0,96	3,93	4,00	3,99	3,97	8	14,33	114,64	110,41			66,7	68,3	0,93	0,89	104,47		
		3	63,86	64,02	63,76	63,88	0,99	3,97	3,99	4,02	3,99	11	14,33	157,63	156,14			63,5	65,1	1	0,96	150,44		
	50%	1	62,15	63,00	62,54	62,56	1,03	4,07	4,04	4,01	4,04	9	14,33	128,97	133,28	138,11	800	66,7	68,3	0,93	0,89	129,61	130,46	800
		2	67,82	68,16	67,58	67,85	0,90	3,97	3,98	3,97	3,97	11	14,33	157,63	142,06			66,7	68,3	0,93	0,89	129,51		
		3	64,25	65,34	64,12	64,57	0,97	4,00	4,02	3,98	4,00	10	14,33	143,30	139,00			65,1	66,7	0,96	0,93	132,28		
	75%	1	65,93	64,18	63,21	64,44	0,99	4,02	3,98	3,97	3,99	10	14,33	143,30	141,37	146,59	800	66,7	68,3	0,93	0,89	135,14	138,03	800
		2	67,23	66,89	67,46	67,19	0,92	3,98	4,00	3,97	3,98	9	14,33	128,97	118,35			66,7	68,3	0,93	0,89	108,68		
		3	63,97	64,50	65,80	64,76	0,97	4,04	3,99	4,01	4,01	13	14,33	186,30	180,04			65,1	66,7	0,96	0,93	170,28		
	100%	1	62,02	62,04	62,51	62,19	1,04	4,08	4,04	4,05	4,06	9	14,33	128,97	134,49	122,34	800	66,7	68,3	0,93	0,89	131,03	116,44	800
		2	64,28	65,08	65,23	64,86	0,97	4,04	4,00	4,01	4,02	9	14,33	128,97	124,58			63,5	65,1	1	0,96	117,53		
		3	65,87	65,35	66,27	65,83	0,94	3,99	4,01	4,00	4,00	8	14,33	114,64	107,97			63,5	65,1	1	0,96	100,78		

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Bachan Kushari, ST, Eng. IPM., ASEAN.Eng.
NIK : 01511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 27 ITS Test Results (48 Hour)

ITS TEST RESULTS
48 Hour of Immersion

Asphalt Optimum Content	Filler Substitution (%)		Sample Thickness (mm)				Corr.	Sample Diameter (Inch)				Stability Dial Gauge			Stability (kg)			Thickness Correction				ITS @ Hour kPa		
			1	2	3	Avg		1	2	3	Avg	Meas	Calibration	Adjust	Initial	Avg	Min	Sample Thickness MIN	Sample Thickness MAX	Correction MIN	Correction MAX	Initial	Avg	Min
6,59%	0%	1	64,55	65,48	64,25	64,76	0,97	3,99	3,96	3,98	3,98	11	14,33	157,63	152,33	129,06	800	55,1	66,7	0,96	0,93	145,39	122,57	800
		2	65,80	64,97	64,60	65,12	0,96	4,01	4,00	4,00	4,00	10	14,33	143,30	137,49			63,5	65,1	1	0,96	129,62		
		3	64,87	64,95	64,23	64,68	0,97	3,99	3,98	4,00	3,99	7	14,33	100,31	97,35			63,5	65,1	1	0,96	92,71		
	25%	1	63,38	62,98	62,79	63,05	1,00	4,02	4,04	4,01	4,02	8	14,33	114,64	114,46	121,18	800	55,1	66,7	0,96	0,93	110,91	116,05	800
		2	64,76	65,08	64,94	64,93	0,96	3,98	3,96	3,98	3,97	11	14,33	157,63	152,01			63,5	65,1	1	0,96	144,83		
		3	65,00	64,80	64,60	64,80	0,97	3,97	3,98	4,00	3,98	7	14,33	100,31	97,05			63,5	65,1	1	0,96	92,42		
	50%	1	63,61	64,57	63,75	63,98	0,98	4,00	4,00	4,00	4,00	7	14,33	100,31	98,41	128,92	800	55,1	66,7	0,96	0,93	94,52	121,45	800
		2	64,86	64,20	64,40	64,49	0,98	4,02	4,00	4,01	4,01	11	14,33	157,63	153,75			63,5	65,1	1	0,96	146,14		
		3	66,36	65,95	66,30	66,20	0,94	4,05	4,04	4,03	4,04	10	14,33	143,30	134,61			55,1	66,7	0,96	0,93	123,70		
	75%	1	64,52	63,97	65,04	64,51	0,97	3,98	4,00	4,00	3,99	12	14,33	171,97	167,62	130,18	800	63,5	65,1	1	0,96	159,93	124,80	800
		2	63,80	62,87	64,02	63,56	0,99	4,00	3,98	3,97	3,98	8	14,33	114,64	113,36			55,1	66,7	0,96	0,93	110,05		
		3	65,45	64,10	66,28	65,28	0,96	3,94	3,96	3,95	3,95	8	14,33	114,64	109,55			63,5	65,1	1	0,96	104,43		
	100%	1	62,73	64,89	66,53	64,72	0,97	4,05	4,00	4,05	4,03	9	14,33	128,97	124,74	110,93	800	55,1	66,7	0,96	0,93	117,46	104,32	800
		2	64,23	64,75	64,50	64,49	0,98	4,06	4,04	4,05	4,05	8	14,33	114,64	111,80			63,5	65,1	1	0,96	105,20		
		3	65,10	64,96	65,32	65,13	0,96	4,01	4,03	4,03	4,02	7	14,33	100,31	96,25			55,1	66,7	0,96	0,93	90,29		

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Badan Kusnadi, M.Eng, IPM., ASEAN.Eng
NIK : 01511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

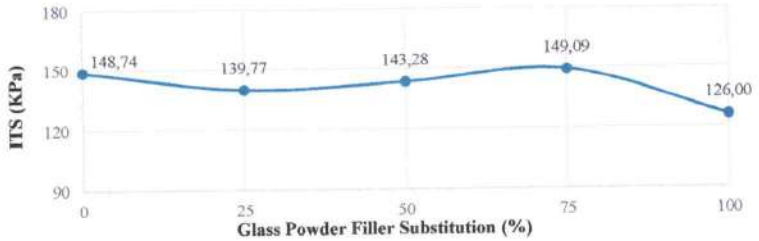
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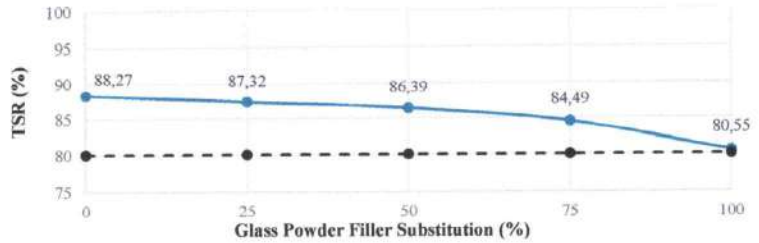
Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 28 Recapitulation of ITS & TSR Test Results (0 Hour)

RECAPITULATION OF ITS & TSR TEST
0 Hour of Immersion

Filler Substitution (%)	OAC (%)	ITS	ITS 24 Hour	TSR (%)
0	6,59	148,739	131,287	88,267
25		139,772	122,046	87,318
50		143,275	123,777	86,391
75		149,092	125,967	84,489
100		126,004	101,492	80,547





Yogyakarta, August 2025

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, M.Eng, IPM., ASEAN.Eng.
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

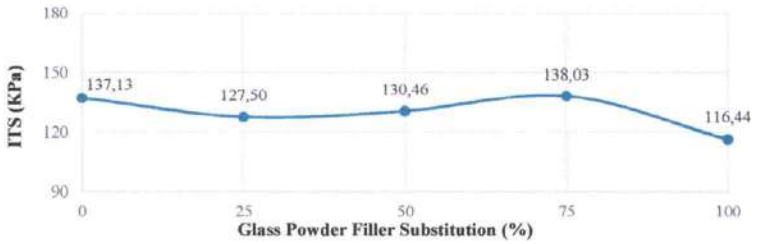
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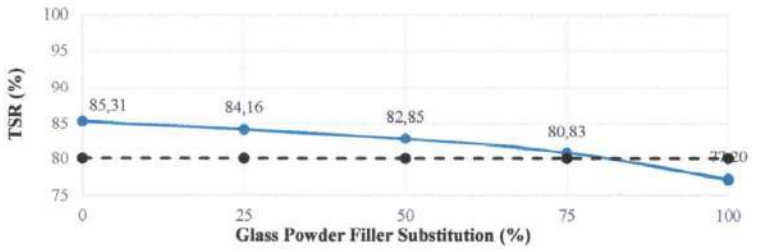
Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 29 Recapitulation of ITS & TSR Test Results (24 Hour)

RECAPITULATION OF ITS & TSR TEST
24 Hour of Immersion

Filler Substitution (%)	OAC (%)	ITS	ITS 24 Hour	TSR (%)
0	6,59	137,130	116,989	85,312
25		127,496	107,302	84,161
50		130,465	108,087	82,847
75		138,033	111,572	80,830
100		116,444	89,897	77,201





Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, M.Eng, IPM., ASEAN.Eng.
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

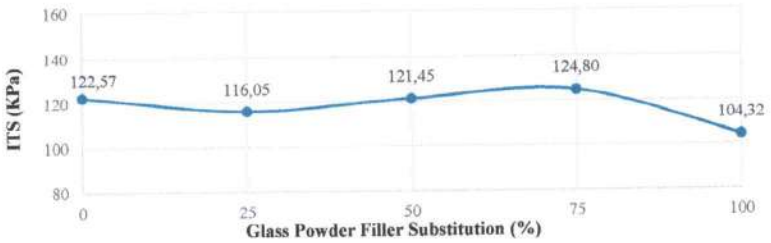
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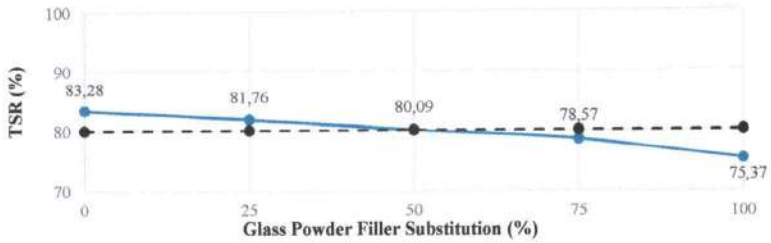
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Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

Appendix 30 Recapitulation of ITS & TSR Test Results (48 Hour)

RECAPITULATION OF ITS & TSR TEST
48 Hour of Immersion

Filler Substitution (%)	OAC (%)	ITS	ITS 24 Hour	TSR (%)
0	6,59	122,573	102,081	83,282
25		116,053	94,880	81,756
50		121,454	97,275	80,092
75		124,804	98,053	78,566
100		104,317	78,624	75,370





Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, M.Eng, IPM., ASEAN.Eng.
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

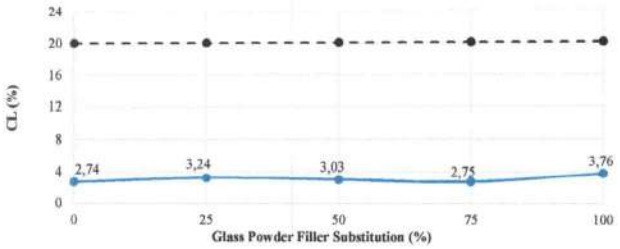
Appendix 31 Cantabro Loss Test Results and Recapitulation (0 Hour)

CANTABRO LOSS TEST RESULTS
0 Hour of Immersion

Filler Substitution	No.	Description	Sample		
			1	2	3
0%	1	Weight Before Abrasion	1199,93	1202,28	1201,37
	2	Weight After Abrasion	1167,16	1170,13	1167,54
	3	Weight Loss Percentage	2,73	2,67	2,82
	4	Average Specific Gravity of Filler	2,74		
25%	1	Weight Before Abrasion	1203,03	1194,27	1199,64
	2	Weight After Abrasion	1161,61	1154,93	1163,76
	3	Weight Loss Percentage	3,44	3,29	2,99
	4	Average Specific Gravity of Filler	3,24		
50%	1	Weight Before Abrasion	1201,86	1195,18	1198,76
	2	Weight After Abrasion	1148,71	1167,61	1170,42
	3	Weight Loss Percentage	4,42	2,31	2,36
	4	Average Specific Gravity of Filler	3,03		
75%	1	Weight Before Abrasion	1195,91	1198,12	1202,65
	2	Weight After Abrasion	1167,24	1163,13	1167,26
	3	Weight Loss Percentage	2,40	2,92	2,94
	4	Average Specific Gravity of Filler	2,75		
100%	1	Weight Before Abrasion	1198,81	1204,42	1201,56
	2	Weight After Abrasion	1157,79	1161,28	1150,15
	3	Weight Loss Percentage	3,42	3,58	4,28
	4	Average Specific Gravity of Filler	3,76		

RECAPITULATION OF CANTABRO LOSS TEST

Filler Substitution (%)	OAC (%)	CL (%)
0	6,59	2,74
25		3,24
50		3,03
75		2,75
100		3,76



Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Bernardus Kushardi, MEng, IPM., ASEAN Eng.
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

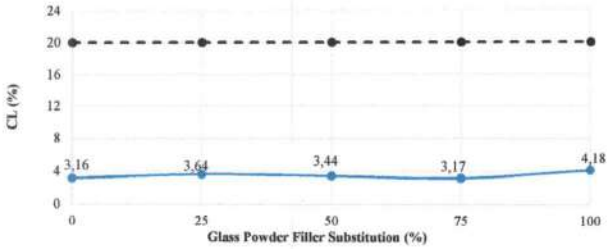
Appendix 32 Cantabro Loss Test Results and Recapitulation (24 Hour)

CANTABRO LOSS TEST RESULTS
24 Hour of Immersion

Filler Substitution	No.	Description	Sample		
			1	2	3
0%	1	Weight Before Abrasion	1201,97	1196,31	1199,17
	2	Weight After Abrasion	1158,85	1164,36	1160,41
	3	Weight Loss Percentage	3,59	2,67	3,23
	4	Average Specific Gravity of Filler	3,16		
25%	1	Weight Before Abrasion	1197,35	1203,06	1199,28
	2	Weight After Abrasion	1156,35	1154,03	1158,27
	3	Weight Loss Percentage	3,42	4,08	3,42
	4	Average Specific Gravity of Filler	3,64		
50%	1	Weight Before Abrasion	1198,73	1202,74	1201,31
	2	Weight After Abrasion	1159,39	1154,40	1164,88
	3	Weight Loss Percentage	3,28	4,02	3,03
	4	Average Specific Gravity of Filler	3,44		
75%	1	Weight Before Abrasion	1199,63	1204,64	1200,33
	2	Weight After Abrasion	1161,37	1164,49	1164,51
	3	Weight Loss Percentage	3,19	3,33	2,98
	4	Average Specific Gravity of Filler	3,17		
100%	1	Weight Before Abrasion	1201,24	1197,36	1202,13
	2	Weight After Abrasion	1154,38	1144,45	1151,36
	3	Weight Loss Percentage	3,90	4,42	4,22
	4	Average Specific Gravity of Filler	4,18		

RECAPITULATION OF CANTABRO LOSS TEST

Filler Substitution (%)	OAC (%)	CL (%)
0	6,59	3,16
25		3,64
50		3,44
75		3,17
100		4,18



Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Bernardus Kushari, M.Eng, IPM., ASEAN.Eng
NIK : 01 5110101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Gedung KH. Moh. Natsir
Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

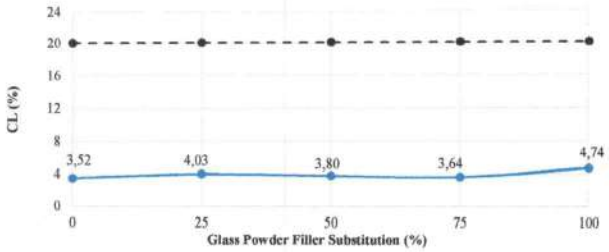
Appendix 33 Cantabro Loss Test Results and Recapitulation (48 Hour)

CANTABRO LOSS TEST RESULTS
48 Hour of Immersion

Filler Substitution	No.	Description	Sample		
			1	2	3
0%	1	Weight Before Abrasion	1202,03	1195,40	1199,72
	2	Weight After Abrasion	1160,28	1152,75	1157,46
	3	Weight Loss Percentage	3,47	3,57	3,52
	4	Average Specific Gravity of Filler	3,52		
25%	1	Weight Before Abrasion	1202,85	1200,22	1198,35
	2	Weight After Abrasion	1151,74	1156,22	1148,29
	3	Weight Loss Percentage	4,25	3,67	4,18
	4	Average Specific Gravity of Filler	4,03		
50%	1	Weight Before Abrasion	1198,49	1195,02	1200,34
	2	Weight After Abrasion	1151,21	1147,26	1158,68
	3	Weight Loss Percentage	3,94	4,00	3,47
	4	Average Specific Gravity of Filler	3,80		
75%	1	Weight Before Abrasion	1201,84	1199,13	1198,14
	2	Weight After Abrasion	1154,12	1158,62	1155,25
	3	Weight Loss Percentage	3,97	3,38	3,58
	4	Average Specific Gravity of Filler	3,64		
100%	1	Weight Before Abrasion	1202,95	1204,95	1200,08
	2	Weight After Abrasion	1148,60	1142,82	1145,41
	3	Weight Loss Percentage	4,52	5,16	4,56
	4	Average Specific Gravity of Filler	4,74		

RECAPITULATION OF CANTABRO LOSS TEST

Filler Substitution (%)	OAC (%)	CL (%)
0	6,59	3,52
25		4,03
50		3,80
75		3,64
100		4,74



Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Berlian Kushari, M.Eng./IPM./ASEAN Eng.
NIK : 01 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhamad Abdul Hadi, S.T., M.T
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

UNIVERSITAS ISLAM INDONESIA

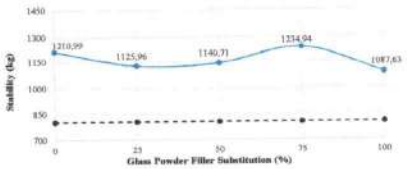
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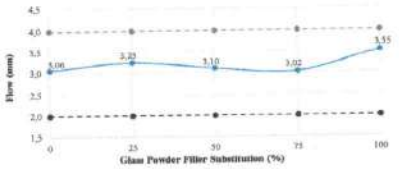
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Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

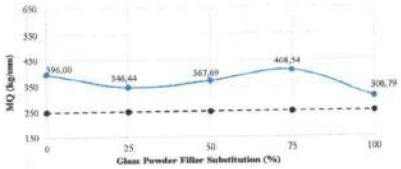
Appendix 34 Recapitulation of Test Results for Glass Powder Filler (0 Hour)

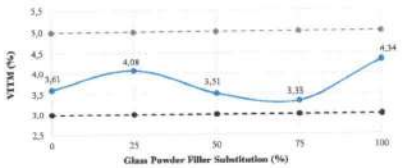
RECAPITULATION OF TEST RESULT AC-BC MIXTURE WITH GLASS POWDER FILLER
0 Hour of Immersion

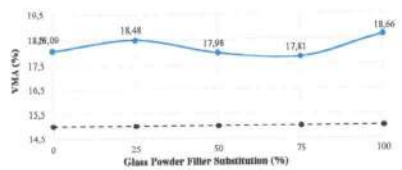
AC-WC Specification	Filler Substitution (%)	Stability 0 Hour (kg)	Flow (mm)	MQ (%)	VITM (%)	VMA (%)	VFWA (kg)	Density (%)	IRS (%)	ITS (kPa)	TSR (%)	CL (%)
	0	1210,99	3,06	396,00	3,61	18,09	80,04	2,29	95,734	148,74	88,27	2,74
	25	1125,96	3,25	346,44	4,08	18,48	78,02	2,27	95,211	139,77	87,32	3,24
	50	1140,71	3,10	367,69	3,51	17,98	80,55	2,28	94,885	143,28	86,39	3,03
	75	1234,94	3,02	408,54	3,33	17,81	81,32	2,29	94,313	149,09	84,49	2,75
	100	1087,63	3,55	306,79	4,34	18,66	76,80	2,26	93,854	126,00	80,55	3,76
BINA MARGA 2018		>800	2 - 4	>250	3 - 5	>15	>68	>2	>90		>80	<20

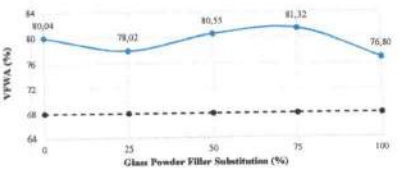


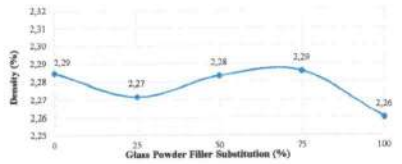


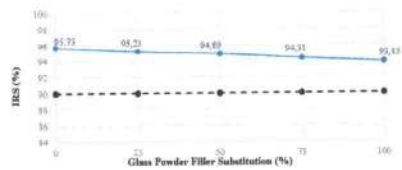


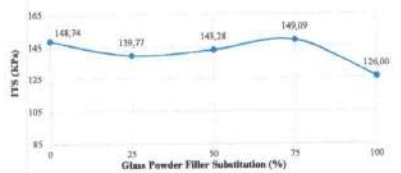


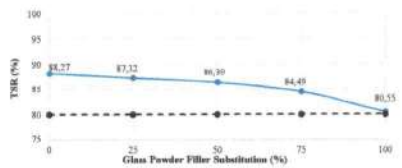


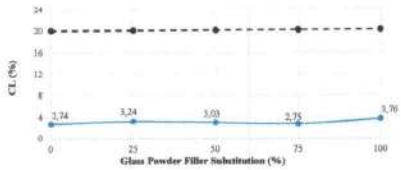












Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Sarlito Kusliani, M.Sc., IPM., ASEAN Eng.
NIK : 05 511 0101

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhammad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

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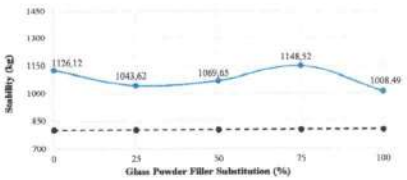
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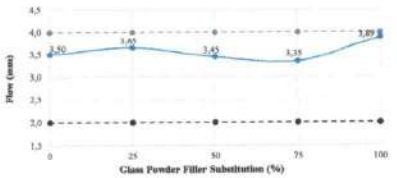
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Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
T. (0274) 898444 ext 3200, 3201
F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

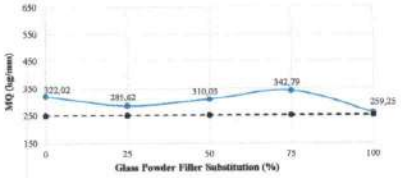
Appendix 35 Recapitulation of Test Results for Glass Powder Filler (24 Hour)

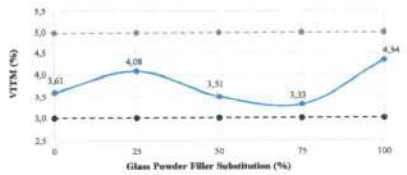
RECAPITULATION OF TEST RESULT AC-BC MIXTURE WITH GLASS POWDER FILLER
24 Hour of Immersion

AC-WC Specification	Filler Substitution (%)	Stability 0 Hour (kg)	Flow (mm)	MQ (%)	VITM (%)	VMA (%)	VFWA (kg)	Density (%)	IRS (%)	ITS (kPa)	TSR (%)	CL (%)
	0	1126,12	3,50	322,02	3,61	18,09	80,04	2,29	93,556	137,13	85,31	3,16
	25	1043,62	3,65	285,62	4,08	18,48	78,02	2,27	92,976	127,50	84,16	3,64
	50	1069,65	3,45	310,03	3,51	17,98	80,55	2,28	92,404	130,46	82,85	3,44
	75	1148,52	3,35	342,79	3,33	17,81	81,32	2,29	92,066	138,03	80,83	3,17
	100	1008,49	3,89	259,25	4,34	18,66	76,80	2,26	91,471	116,44	77,20	4,18
BINA MARGA 2018		>800	2 - 4	>250	3 - 5	>15	>68	>2	>90		>80	<20

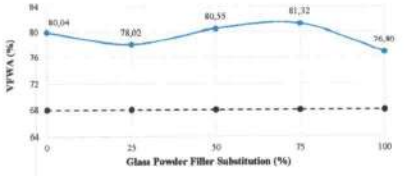


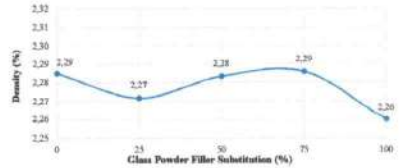


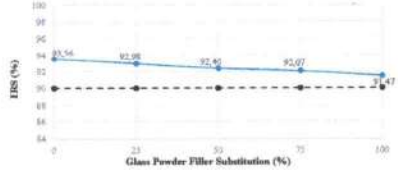


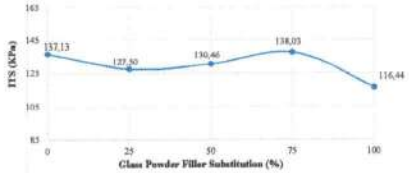


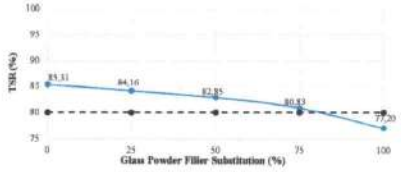


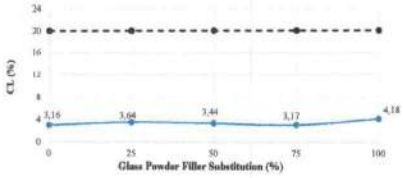












Acknowledged by
Laboratory Management Civil Engineering Dept.

Ir. Faisal Fathani, M.Eng, IPM., ASEAN Eng.
NIK : 01 911 0161

Acknowledged by
Head of Highways Engineering Lab.

Ir. Muhammad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Yogyakarta, August 2025
Researcher

Gading Ananda Syahri
NIM : 20 511 012

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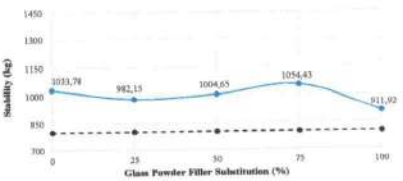
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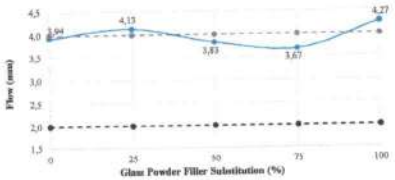
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Kampus Terpadu Universitas Islam Indonesia
Jl. Kaliurang km 14,5 Yogyakarta 55584
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F. (0274) 895330
E. dekanat.ftsp@uii.ac.id
W. ftsp.uii.ac.id

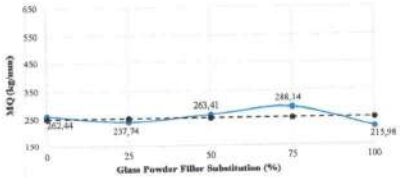
Appendix 36 Recapitulation of Test Results for Glass Powder Filler (48 Hour)

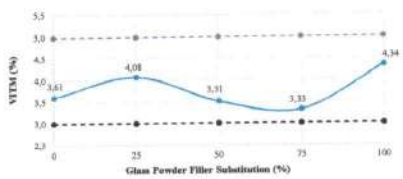
RECAPITULATION OF TEST RESULT AC-BC MIXTURE WITH GLASS POWDER FILLER
48 Hour of Immersion

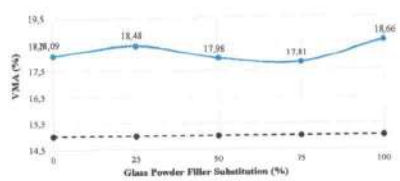
AC-WC Specification	Filler Substitution (%)	Stability 0 Hour (kg)	Flow (mm)	MQ (%)	VITM (%)	VMA (%)	VFWA (kg)	Density (%)	IRS (%)	ITS (kPa)	TSR (%)	CL (%)
	0	1033,78	3,94	262,44	3,61	18,09	80,04	2,29	91,617	122,57	83,28	3,52
	25	982,15	4,13	237,74	4,08	18,48	78,02	2,27	91,263	116,05	81,76	4,03
	50	1004,65	3,83	263,41	3,51	17,98	80,55	2,28	90,756	121,45	80,09	3,80
	75	1054,43	3,67	288,14	3,33	17,81	81,32	2,29	90,221	124,80	78,57	3,64
	100	911,92	4,27	215,98	4,34	18,66	76,80	2,26	89,712	104,32	75,37	4,74
BINA MARGA 2018		**>800**	**2 - 4**	**>250**	**3 - 5**	**>15**	**>68**	**>2**	**>90**		**>80**	**<20**

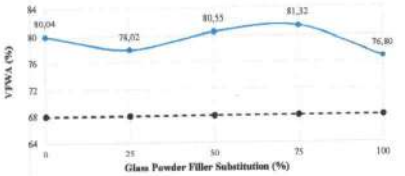


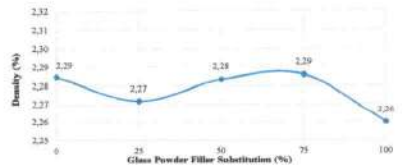


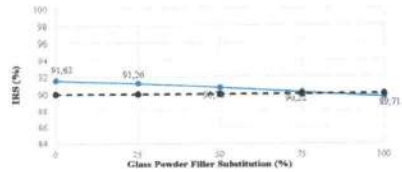


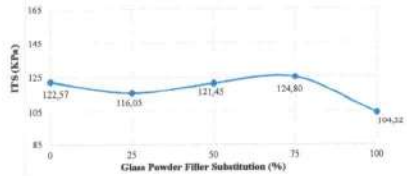


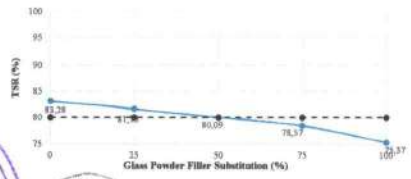


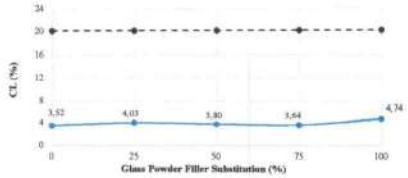












Yogyakarta, August 2025

Researcher

Gading Ananda Syahri
NIM : 20 511 012

Acknowledged by
Head of Highway Engineering Lab.

Ir. Muhammad Abdul Hadi, S.T., M.T.
NIK : 21 511 1307

Approved by
Laboratory Manager of Civil Engineering Dept.

Ir. Nurmi Kasihani, M.Eng., Ph.D., IPM., ASEAN Eng.
NIK : 885 100 109